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In-Plant Control of Process Wastewater

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The first volume explains the basics of pollution control and presents case histories from the fruit and vegetable industry. Volume 2 discusses in-plant control of process wastewater encompassing analysis of plant processes, factors influencing waste generation, and in-plant modifications and effects. Volume 3 offers a general understanding of wastewater treatment technology that will enable truit and vegetable processors to deal more effectively with regulatory agencies and their own waste disposal situations.

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In-Plant Control of Process Wastewater

ENVIRONMENTAL PROTECTION AGENCY
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July 1977

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NOTICE

The mention of trade names or commercial products in this publication is for illustration purposes, and does not constitute endorsement or recommendation for use by the U.S. Environmental Protection Agency.

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Chapter I

INTRODUCTION

The use of water is inherent to processing operations associated with the preparation and preservation of fruits and vegetables.

- Water is in intimate contact with most foods during their preparation and processing. It is universally used for washing raw commodities and is used as an ingredient in formulation of many foods, often serving as the sole or principal packing medium.
- Water is the vehicle for transfer of power and heat. It is used to transport raw materials to and from unit operations. Vegetables are immersed in hot water or exposed to live steam in blanching to inactivate enzymes and to wilt leafy vegetables to facilitate their filling into suitable containers.
- Water is the primary agent used for cleaning and sanitizing processing equipment; these steps are essential to assuring the production of nutritious and wholesome foods.

With the exception of the water used in steam production and used as the packing medium for canned products, all other uses result in the generation of wastewaters containing various concentrations of pollutants which are largely organic in nature.

Pollution control of all industrial wastewaters has been legislated on the national level by the Federal Water Pollution Control Act Amendments of 1972 (FWPCA), and on the state level by numerous laws enacted before and since the FWPCA. These laws, as well as the myriad of regulations precipitated thereby, necessitate careful management of industrial wastewaters, beginning with minimization of pollutant generation, followed by proper collection and handling, and ultimately concluding with adequate treatment and disposal.

The following chapters of this volume deal primarily with measures which can be used to reduce water consumption and minimize pollutant generation through proper management of food processing operations; that is, pollution controls within food processing plants. Pollution controls through treatment and proper disposal are discussed in a separate volume. These chapters are intended to serve as guides for planning and implementing pollution abatement programs.

Chapter II

DATA ACCUMULATION

Planning and implementation of effective water conservation and/or waste treatment and disposal programs necessitate the availability of factual data accumulated from each step in the fruit and vegetable processing plant. The accumulation of this necessary information can be assured only through a well-planned and carefully executed water-wastewater survey program. Some items of information which must be developed during such surveys are:

- The locations of both fresh water and wastewater flows within the plant.
- The volumes of water utilized and discharged by each unit operation.
- The pollutional load generated by each unit operation.
- The hydraulic and organic load (raw waste load) of the plant effluent for each product or product combination.

THE IN-PLANT SURVEY

The information collected during an in-plant survey is especially useful for two purposes:

1. For use in an in-plant pollution control program. The survey should be designed to critically evaluate each processing unit with the objective of reducing waste loads at the point of generation. Operations in which water is being excessively used will be quickly identified, enabling corrective measures to be taken to reduce these obvious contributions to the hydraulic load. Further reductions in water consumption, and hence, wastewater generation, will be possible through water reuse systems which can be efficiently designed with the data collected during the survey program.

2. For use in the design of a treatment facility which will adequately reduce all waste loads to the level required for discharge to a receiving stream. The data collected during the survey should include the physical and chemical characteristics of each waste stream. Relatively clean wastewater sources can then be identified, and segregation for separate disposal or reuse can be considered. Waste streams containing high concentrations of pollutants can be characterized and appropriate treatment systems designed for their disposal; users of municipal facilities will be able to predict their sewer service charges with appropriate data.

The survey program is an intensive data-collecting project which can be accomplished during the course of a single season. Suggested procedures for such a program are outlined below. Details pertaining to each of these steps may be found in the remaining sections of this chapter.

1. Draw a map of the plant, indicating all water supply lines and wastewater flows.

2. Select appropriate methods of flow measurement. Install measuring devices where necessary.

3. Select sample collection sites and establish a sampling schedule. The survey program should be designed to develop data which reflect changes in waste characteristics that inherently occur throughout the season.
4. Determine laboratory analyses to be made. Review test procedures to determine chemicals and equipment required.
5. Proceed with development of data.
6. Correlate production records (tons of raw product processed or cases of finished product produced) to water flows and to laboratory results. The accumulated data can then be used to predict estimated effects of subsequent operational changes, such as equipment modifications, production changes, and water conservation measures.

MONITORING PROGRAM

The primary purpose of a wastewater monitoring program is to provide information by which the operating efficiency of pollution control programs can be evaluated. As a minimum, continuous monitoring of the plant effluent stream(s) and treatment system discharge(s), when applicable, should be conducted. The in-plant survey previously described may indicate additional desirable monitoring points.

Since monitoring information is continuously gathered and should be routinely recorded, it is convenient to provide permanently installed equipment for measuring and recording flows, and for collecting representative samples of wastewater for laboratory analysis. Various types of equipment are discussed in the ensuing sections.

Although the purpose of a monitoring program differs somewhat from that of a survey program, the basic information collected is essentially identical. Suggested procedures are outlined below. Details of each step are described in the remaining sections of this chapter.

1. Revise the map drawn for the in-plant survey to reflect any modifications which may have been made to the water and wastewater flows. Expand the map to include existing wastewater treatment/disposal facilities.
2. Select appropriate monitoring points for each wastewater stream being discharged from the plant, as well as appropriate points in the existing wastewater treatment facility.
3. Install suitable flow measuring and recording devices at appropriate locations. If practical, also install suitable automatic sampling equipment at these locations.
4. Establish a sampling schedule which will assure the collection and analysis of samples at frequencies sufficient to detect and avert potential major water pollution problems.
5. Keep permanent records of all collected data, including corresponding production records and waste treatment/disposal costs.

FLOW MEASUREMENT

An essential part of the survey or monitoring program is the collection of flow data. A variety of flow measuring methods and devices are available. Selection of an appropriate method for the measurement of water used by unit operations or of flows in in-plant waste streams will be influenced by the physical arrangement of each system and by the desired degree of data accuracy. Some methods for measuring flows in various types of systems are discussed in this chapter.

Emphasis has been placed on methods which yield reliable estimates without necessitating expensive apparatus. These methods will prove satisfactory for in-plant surveys. However, for continuous monitoring programs, permanent flow measuring and recording installations are recommended[1].

VOLUMES TO UNIT OPERATIONS

In-plant waste collection systems are often inaccessible or are arranged in such a manner that it is virtually impossible to segregate flows originating from separate operations. Under these conditions, the easiest means to determine the volume contribution from each operation to the composite plant effluent is to measure the volume of water used by each. However, caution should be exercised in the determination of flows by this method. Any portion of water from a unit operation which is reused in a separate operation must be noted and properly accounted for.

Container and Stopwatch

The simplest and least expensive method for measuring flows is by the container and stopwatch technique. Although this method is rather crude when compared to the sophisticated equipment and devices which are available, reasonable estimates can be obtained. Flows are determined by recording the time required to fill a container of known volume. For greater accuracy, the following should be observed:

1. A stopwatch, rather than an ordinary clock, should be used.
2. Containers which require more than 10 seconds to fill should be used to minimize observational errors.

Calculate the capacity of rectangular or cylindrical containers by the following formulae:

1. Volume (gallons) of rectangular box $= \text{length (ft)} \times \text{width (ft)} \times \text{depth (ft)} \times 7.48$

or

$$\frac{\text{length (in)} \times \text{width (in)} \times \text{depth (in)}}{231}$$

2. Volume (gallons) of cylinder $= (\text{diameter, ft})^2 \times \text{depth (ft)} \times 5.87$

or

$$\frac{(\text{diameter, in})^2 \times \text{depth (in)}}{294}$$

If an irregular-shaped container, such as a bucket, is used, its capacity may be determined as follows:

1. Weigh the empty container.
2. Fill the container with water and weigh again.
3. Calculate the capacity by:

$$\text{Volume (gallons)} = \frac{\text{filled weight (lbs)} - \text{empty weight (lbs)}}{8.34}$$

If water to an operation is from a single pipe, a container can readily be placed to collect the influent stream. If, however, the influent water is difficult to collect in a single container, as in the case of a bank of sprays, a suitable catch basin can be used to initially collect the water flow. The collected flow can then be diverted to the measuring container. Determine the flow in the following manner:

1. If a catch basin is required, place it in a suitable position taking care that water will not be lost over its sides.
2. Turn on the water supply to the operation. Be certain that flow rates are as close to operating conditions as possible.
3. Place the container in position to collect *all* the water from the catch basin. Simultaneously start the timer (stopwatch).
4. When the measuring container has filled to capacity (or to a predetermined level), immediately stop the timer.
5. For greatest accuracy, repeat the procedure several times and use the average interval to calculate the flow.
6. Calculation:

$$Q\text{, flow in gallons per minute (gpm)} = \frac{\text{volume of container (gal)}}{\text{time required to fill (seconds)}} \times 60$$

Water Meters

For convenience and greatest accuracy, the installation of in-line meters on influent water lines is recommended. A wide variety of flow meters, rate indicators and other devices for observing or recording flows in pressurized pipes are commercially available. Due to the widespread use of these devices and the ready availability of detailed information from numerous manufacturers, only the commonly-used, propeller-type flow meter is included in this discussion.

The propeller-type flow meter, schematically illustrated in figure II-1, consists of a propeller, or a similar rotor, placed within a pipeline. The propeller turns in direct relation to the velocity of fluid flow in the pipe. By means of calibrated gears, the rotations are converted to volumes which are visually observable on the dial (or register) normally contained in the unit. Flow rates can be obtained by using a stopwatch while observing the meter dial.

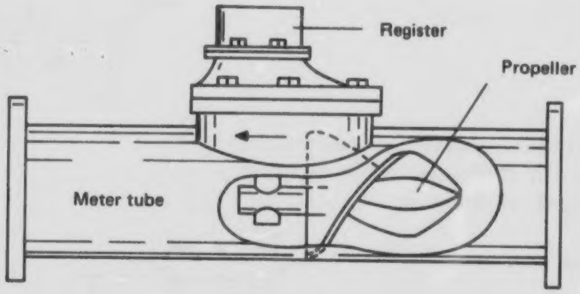


Figure II-1. Propeller-type flow meter.

Accurate measurements with propeller-type meters require the maintenance of close tolerances between the propeller blades and the inside surface of the pipe or meter casing. This requirement precludes the use of these meters in pipelines carrying large solid material. However, these meters are excellent for measuring and recording the volume of water entering the plant and the volumes utilized by individual operations within the plant. Meter accuracy should be protected by regular maintenance and ascertained by periodic calibration.

FLOWS IN OPEN CHANNELS

Open channels are commonly used in fruit and vegetable processing plants. These include flumes and gutters used for the hydraulic transport of product within the plant as well as flumes, gutters and ditches used for the collection and transport of liquid waste streams within and away from the plant. The flow of water in these systems can be:

1. Estimated by measuring the depth and velocity of flow in the channel, or

2. Measured with the use of a suitable device, such as a weir or Parshall flume.

Depth and Velocity of Flow Method

A reasonable estimate of the flow in an open channel can be derived from observation of the velocity, or rate of flow, within the channel and measurement of the cross-sectional area of the water. Close approximation of actual flow can be obtained by using 85 percent of the measured surface flow. The rate of flow is estimated by recording the time required for a floating object to travel between two points of the channel.

The accuracy of results obtained by this method is improved when:

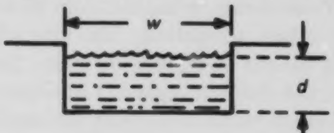
1. The flow in the channel is constant, and

2. The bottom and walls of the channel are smooth and of even dimensions along the section where the measurements are taken.

Measure the cross-sectional area (A) of the channel in one of the following ways:

1. For rectangular channels:

   A = width x depth

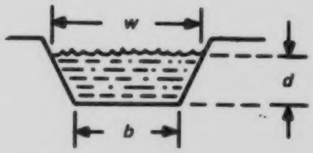


2. For trapezoidal channels:

   $A = \frac{(w+b)}{2}$ x depth

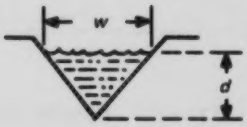
   where:

   w = width of channel at water surface
   b = width of channel at the bottom
   d = depth of channel



3. For triangular channels:

   $A = \frac{\text{width x depth}}{2}$



Determine the flow in the following manner:

1. Select a straight portion of the channel, if possible, of sufficient length to require at least 10 seconds for a float to traverse the distance.
2. Place a marker at each end of this stretch. Measure the distance between the two points.
3. Calculate the cross-sectional area of the channel as outlined above. If the dimensions of the channel are irregular, make several measurements along the selected length and use the average for calculation.
4. Place a float (a piece of wood or cork or an empty, sealed can) on the water at a distance slightly upstream from the first marker.
5. Using a stopwatch, time the interval required by the float to traverse the distance between the markers. Repeat several times and use the average for calculation.
6. Calculation:

$$Q\text{ (gpm)} = \frac{\text{area (ft}^2\text{) x length (ft)}}{\text{t (seconds)}} \times 449 \times 0.85$$

$$Q\text{ (gpm)} = \frac{\text{area (in}^2\text{) x length (in)}}{\text{t (seconds)}} \times 0.26 \times 0.85$$

Weirs

A weir is an inexpensive device for measuring flows in open channels. As illustrated in figure II-2, it is simply a barrier or dam containing a recess or notch, through which water flows to fall freely to a level below the bottom of the recess or notch. The height of the water passing over the weir varies with the volume of water flowing in the stream. Thus, flows are determined by measuring the head (i.e., the depth of the stream between the bottom of the recess and the water surface) at an appropriate distance behind the weir (figure II-3).

Various shapes are used in the construction of these devices. The more common forms are V-notch, rectangular, and trapezoidal. Selection of a weir shape is determined by the flow rate and the dimensions of the channel. Flow rates over a 90° V-notch weir are provided in table II-1. Tables for other weir configurations are available in several references, including the EPA's *Handbook for Monitoring Industrial Wastewater*[1] and in the *Guide for Waste Management in the Food Processing Industry*[2] published by the National Canners Association. By referring to these tables, a properly designed weir can be constructed in the following manner:

1. Estimate the maximum waste flow that can be expected. The depth-velocity or container and stopwatch methods are useful for this purpose.

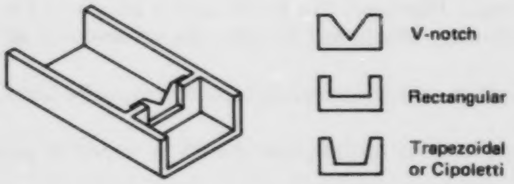


Figure II-2. Common forms of weir plates.

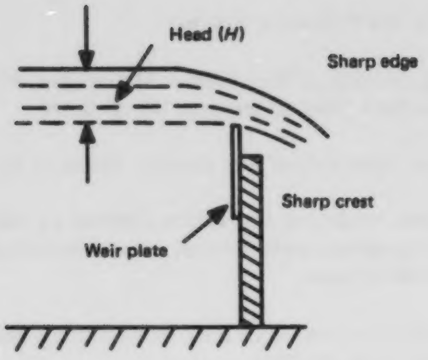


Figure II-3. Flow over sharp-crested weir.

2. Select one of the weir types and find the head over the weir corresponding to the estimated maximum flow by referring to the appropriate table.

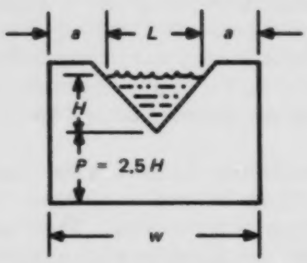
3. The total depth for maximum flow should be at least 3.5 times *H*, the head, as found in Step 2.

4. Compare this to the actual depth of the channel in which the flows are to be measured. Allow at least two inches to insure against flooding caused by back-up of water in the gutter.

5. Check the lateral dimensions to see if the channel width fulfills the specifications for the type of weir selected:

    (a) For a 90° V-notch weir, the width of each end contraction, *a*, must be at least 1.5 times *H*. Thus, the width of the channel should be at least 4 times *H*.

    (b) For a standard rectangular weir, the width of each end contraction, *a*, should be greater than 2.5 times *H*. Thus, $w > 5H + L$.



    (c) For rectangular weirs with modified end (trapezoidal) contractions, the width of each end contraction need only be large enough to permit the free passage of air between the walls of the channel and the flow of water passing over the weir.

The rectangular weir with modified end contractions appears to be the best design for general use since most gutters and flumes in fruit and vegetable processing plants are too narrow to permit the use of a V-notch weir. However, this latter type is excellent for measurement of small flows. Observation of the following points will increase the accuracy of all weir measurements:

1. The weir plate must be vertical and the top must be level.

2. The sides and bottom of the plate should be sealed to prevent leakage.

Table II-1.—*Discharge over 90° V-notch weir*

Note — Total width of two end contractions = 2*a* = 1.5*L*
where "*a*" = width of each contraction
"*L*" = width of water flowing over weir

Head (*H*) inches	Discharge gallons per minute (gpm)
1	2
1/4	4
1/2	6
3/4	9
2	12
1/4	17
1/2	24
3/4	30
3	37
1/4	45
1/2	53
3/4	65
4	76
1/4	88
1/2	100
3/4	114
5	129
1/4	149
1/2	166
3/4	183
6	204
1/4	225
1/2	247
3/4	276
7	300
1/4	332
1/2	354
3/4	383
8	413
1/4	451
1/2	486
3/4	520
9	555
1/4	594
1/2	632
3/4	684
10	725
1/2	815
11	910
1/2	1040
12	1130
1/2	1250
13	1380
1/2	1520
14	1650
1/2	1810
15	1970
1/2	2120
16	2310
1/2	2480
17	2670
1/2	2880
18	3080
1/2	3290
19	3530
1/2	3760
20	4000
1/2	4250
21	4500
1/2	4770

3. The weir can be of wood or metal. A metal plate bolted to the upstream side of a wood section will make a satisfactory weir. The crest should be 1/8" to 1/4" thick and sharp-edged. If the weir is thicker, the top should be beveled to this dimension on the downstream face.

4. The crest height, *P*, should be at least 2.5 times the maximum expected head, *H*. Settleable solids, which may accumulate behind the weir, may change this dimension, thereby introducing errors in observed flows. Therefore, the channel must be regularly cleared of settleable material.

5. The head should be measured at a point upstream from the weir at a distance of at least 4 times that of the maximum expected head. A staff gauge or rule (the zero mark of which is level with the crest of the weir) can be attached to the wall of the channel for this purpose.

Parshall Flume

The Parshall flume is a convenient device for measuring the flow in existing waste flows and consists of three parts: a converging section, a throat section, and a diverging section. The dimensions and capacities of Parshall flumes are shown in figure II-4. The level of the floor in the converging section is higher than the floor in the throat and diverging sections. The head of the water surface in the converging section is a measurement of the flow through the flume.

The elevation of the water surface should be measured back from the crest of the flume at a distance equal to 2/3 of the length of the converging section. The crest is located at the junction of the throat and converging section. The head should be measured in a stilling well instead of in the flume itself as sudden changes in flow are dampened in a stilling well. The size of the Parshall flume should be determined during the preliminary survey. The general formula for computing the free discharge from a Parshall flume is as follows:

$$Q = 4\,W H^{n}$$

where:

Q = discharge, cfs

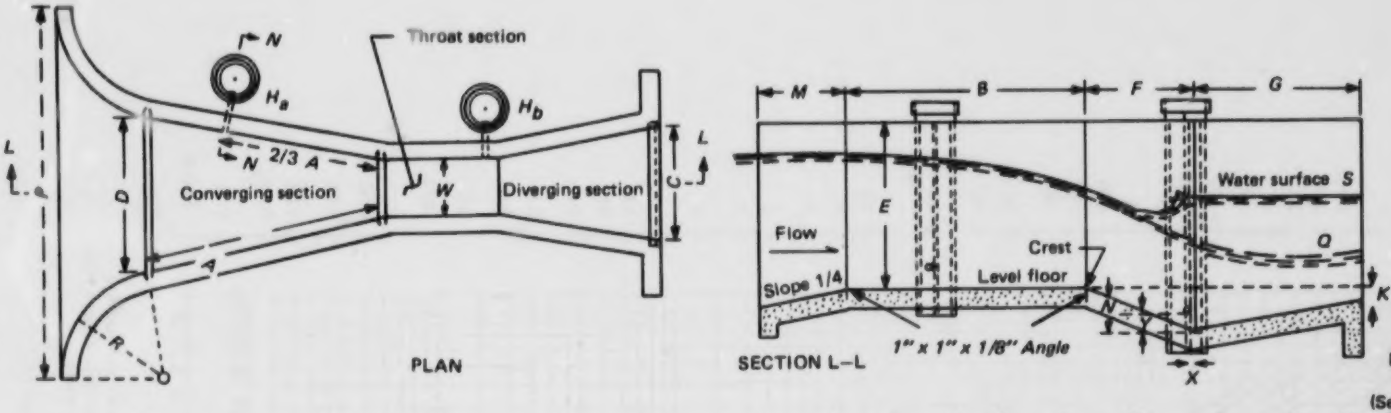
W = throat width, ft

H = head of water above the level floor in ft in the converging section

$n = 1.522\,W^{0.026}$

The flume may be built of wood, fiberglass, concrete, plastic or metal and can be installed at convenient locations, such as a manhole. The Parshall flume is used for sewer lines where continuous-flow measurements are desirable. The main advantage of the Parshall flume over a weir is the self cleaning properties of the flume. Accurate measurements can be made even if the flow is submerged as shown by the water levels in figure II-5.

The flow can become submerged due to high water elevations downstream. If the flow is submerged, a velocity reduction in the flow occurs. The degree of submergence must be determined in order to measure the flow accurately since the flume is calibrated for free flow conditions. The condition of submerged flow is evidenced by a ripple or wave formed just downstream from the end of the throat. A reduction in the velocity of the water leaving the flume may lessen the effects of erosion downstream. In order to determine the degree of submergence, a stilling well must be built



PLAN

SECTION L–L

W		A		2/3 A		B		C		D		E		F		G		K	N	R		M		P		X	Y	Free-Flow Capacity (Second-Foot*)	
Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	In.	In.	Ft	In.	Ft	In.	Ft	In.	In.	In.	Minimum	Maximum
0	3	1	6-3/8	1	1/4	1	6	0	7	0	10-3/16	2	0	0	6	1	0	1	2-1/4	1	4	1	0	2	6-1/4	1	1-1/2	0.03	1.9
0	6	2	7/16	1	4-5/16	2	0	1	3-1/2	1	3-5/8	2	0	1	0	2	0	3	4-1/2	1	4	1	0	2	11-1/2	2	3	0.05	3.9
0	9	2	10-5/8	1	11-1/8	2	10	1	3	1	10-5/8	2	6	1	0	1	6	3	4-1/2	1	4	1	0	3	6-1/2	2	3	0.09	8.9
1	0	4	6	3	0	4	4-7/8	2	0	2	9-1/4	3	0	2	0	3	0	3	9	1	8	1	3	4	10-3/4	2	3	0.11	16.1
1	6	4	9	3	2	4	7-7/8	2	6	3	4-3/8	3	0	2	0	3	0	3	9	1	8	1	3	5	6	2	3	0.15	24.6
2	0	5	0	3	4	4	10-7/8	3	0	3	11-1/2	3	0	2	0	3	0	3	9	1	8	1	3	6	1	2	3	0.42	33.1
3	0	5	6	3	8	5	4-3/4	4	0	5	1-7/8	3	0	2	0	3	0	3	9	1	8	1	3	7	3-1/2	2	3	0.61	50.4
4	0	6	0	4	0	5	10-5/8	5	0	6	4-1/4	3	0	2	0	3	0	3	9	2	0	1	6	8	10-3/4	2	3	1.3	67.9
5	0	6	6	4	4	6	4-1/2	6	0	7	6-5/8	3	0	2	0	3	0	3	9	2	0	1	6	10	1-1/4	2	3	1.6	85.6
6	0	7	0	4	8	6	10-3/8	7	0	8	9	3	0	2	0	3	0	3	9	2	0	1	6	11	3-1/2	2	3	2.6	103.5
7	0	7	6	5	0	7	4-1/4	8	0	9	11-3/8	3	0	2	0	3	0	3	9	2	0	1	6	12	6	2	3	3.0	121.4
8	0	8	0	5	4	7	10-1/8	9	0	11	1-3/4	3	0	2	0	3	0	3	9	2	0	1	6	13	8-1/4	2	3	3.5	139.5

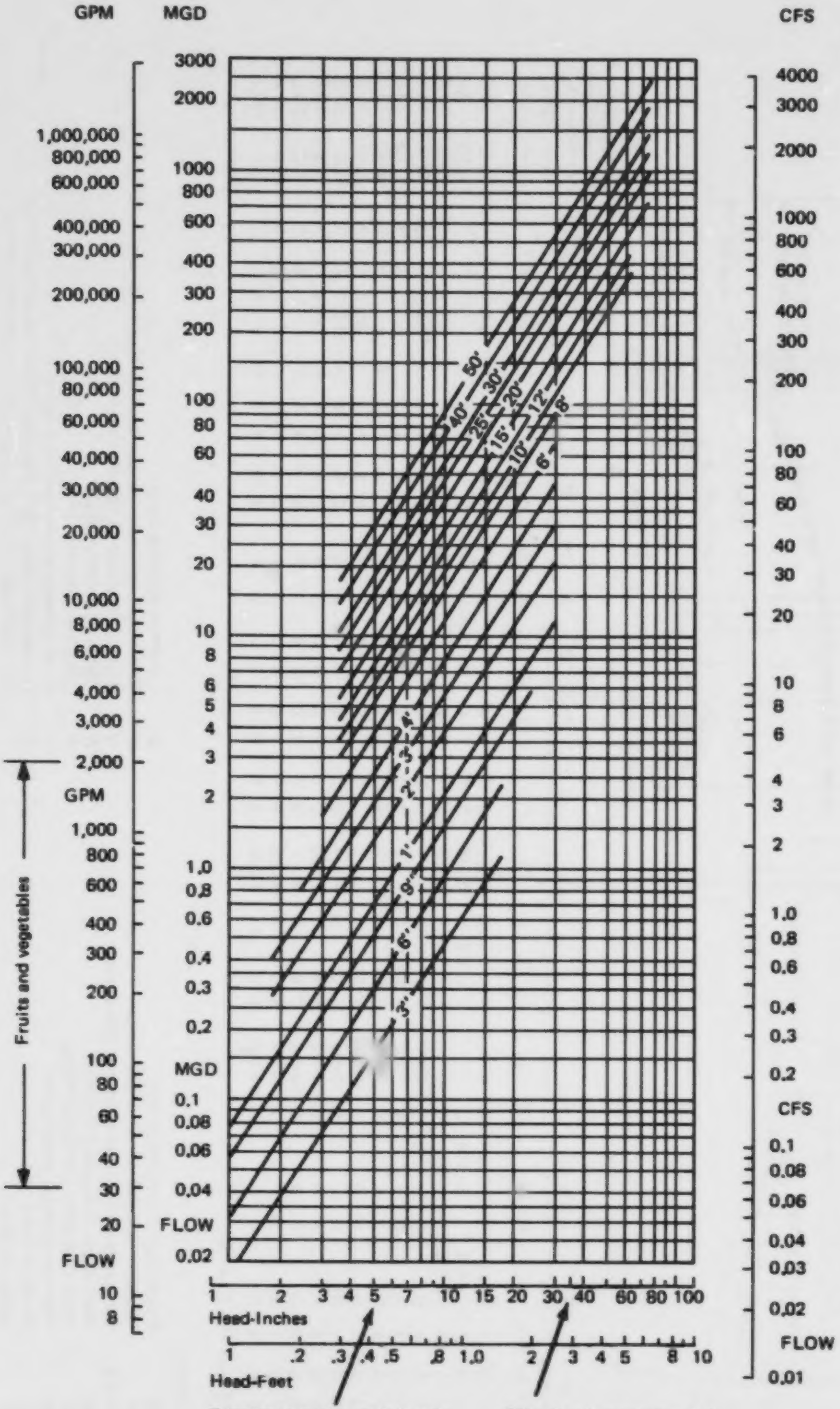
*Equals 1 cu ft per sec.

Legend:

W	Size of flume, in inches or feet.
A	Length of side wall of converging section.
2/3 *A*	Distance back from end of crest to gage point.
B	Axial length of converging section.
C	Width of downstream end of flume.
D	Width of upstream end of flume.
E	Depth of flume.
F	Length of throat.
G	Length of diverging section.
K	Difference in elevation between lower end of flume and crest.
N	Depth of depression in throat below crest.
R	Radius of curved wing wall.
M	Length of approach floor.
P	Width between ends of curved wing walls.
X	Horizontal distance to *H*, gage point from low point in throat.
Y	Vertical distance to *H*, gage point from low point in throat.

Source: *ORSANCO* (1952).

Figure II-4. Dimensions and capacities of the Parshall measuring flume, for various throat widths, *W*(4).[1]



5 inches is minimum full scale head with Foxboro float and cable meter

36 inches is maximum full scale head with Foxboro float and cable meter

Figure II-5. Flow curves for Parshall flumes.[1]

in the throat section. The crest elevation in the throat section is H_b and the head in the converging section is H_a. The ratio H_a/H_b is a measurement of the submergence. The stilling well used to measure H_b should be located near the downstream end of the throat section and the datum for H_a and H_b is the level floor of the converging section.

FLOWS IN PARTIALLY FILLED PIPES

Measurement of flows in partially filled pipes can be taken by several methods depending upon physical convenience. Where sections of pipe are exposed, a segment can be removed and substituted with a Parshall flume or weir box as previously discussed. If a straight nonconstricted run of pipe is accessible at both ends, flow estimates can be obtained by the depth-velocity methods. For this purpose, table II-2 lists cross-sectional areas of water at various depths for several pipe diameters. Calculation of flow is the same as for open channel flow measurement.

For round-bottom channels or pipelines accessible through manholes or other openings, the Palmer-Bowlus metering flume is an inexpensive and easily installed device. The Palmer-Bowlus flume may be nothing more than a level section of floor placed into a waste flow, which is a major advantage over the Parshall flume. The length of the floor should be approximately the same as the diameter of the conduit. The flume is positioned at the bottom of the conduit. It provides a slight restriction or throat which creates an upstream head of water.

Figure II-6 shows a few possible forms of the Palmer-Bowlus flume. The materials used to build the flume may be cast iron, stainless steel, fiberglass or concrete. This type of flume is easily installed in existing waste flows as no drop in head is required. The critical depth will be at the top of the level floor. The flow through a Palmer-Bowlus flume may be represented by the following equation:

At critical flow:

$$\frac{Q^2}{g} = \frac{A_c^3}{b} \quad \text{and} \quad \frac{V_c^2}{2g} = \frac{A_c}{2b} = \frac{d_c}{2}$$

where:

A_c = area at the critical depth, ft^2

d_c = critical depth, ft

V_c = critical velocity

b = width of flume

No field calibration is necessary for this type of measuring device and its accuracy is comparable to that of a Parshall flume. A reasonably accurate measurement of flow can be obtained with upstream depths as great as 0.95 of the pipe diameter, provided sensitive instrumentation is used and flows upstream to and through the unit are not turbulent.

FLOWS FROM OPEN-END PIPES

In most cases where pipes are used for in-plant transport of wastewater, the only practical point for flow measurement is at the discharge end of the system. Several methods and devices are suitable for use at this point.

Table II-2.—*Cross-sectional area of water in pipes at various depths of flow*

Depth of flow *(d)* inches	Cross sectional area — square feet (sq ft)				
	Diameter of pipe *(D)* — inches				
	6	8	10	12	15
2	.06	.07	.08	.09	.10
1/4	.07	.08	.09	.10	.12
1/2	.08	.09	.11	.12	.13
3/4	.09	.11	.12	.14	.15
3	.10	.12	.14	.15	.17
1/4	.11	.13	.15	.17	.20
1/2	.12	.15	.17	.19	.22
3/4	.13	.16	.19	.21	.24
4	.14	.17	.20	.23	.27
1/4	.15	.19	.22	.25	.29
1/2	.16	.20	.24	.27	.31
3/4	.17	.22	.26	.29	.33
5	.17	.23	.27	.31	.36
1/4	.18	.24	.29	.33	.38
1/2	.19	.26	.31	.35	.41
3/4	.19	.27	.32	.37	.43
6	.20	.28	.34	.39	.46
1/4		.29	.36	.41	.48
1/2		.30	.38	.43	.51
3/4		.31	.39	.45	.54
7		.32	.41	.48	.56
1/4		.33	.42	.50	.59
1/2		.34	.44	.52	.62
3/4		.35	.45	.54	.64
8		.35	.47	.56	.67
1/4			.48	.58	.69
1/2			.49	.59	.72
3/4			.51	.61	.74
9			.52	.63	.77
1/4			.53	.65	.79
1/2			.54	.67	.82
3/4			.54	.68	.84
10			.55	.70	.87
1/4				.71	.89
1/2				.73	.92
3/4				.74	.94

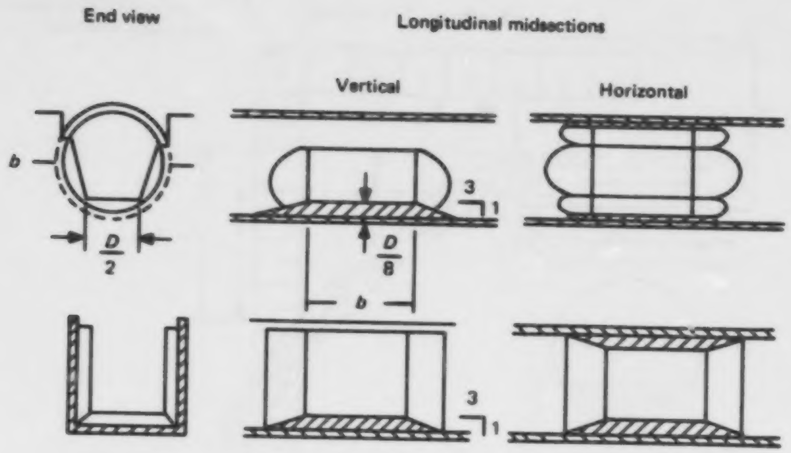


Figure II-6. Various shapes of Palmer-Bowlus flumes.

Container and Stopwatch

If the flow to be measured can be readily captured in a container of practical dimensions, the container and stopwatch technique (as previously described) can be employed. To minimize observational errors, the container should be large enough to require at least 10 seconds to fill.

Coordinate Method

This method can be used when the water discharges freely from the end of an open pipe. The calculation is derived from the physics principle of trajectory which relates the distance of a particle from a point to the velocity of that particle at the point of origin.

As illustrated in figure II-7, the position of the water after it has left the pipe is measured by the horizontal distance (*X*) and the vertical distance (*Y*) from the end of the pipe. *Y* must be a vertical distance and *X* must be parallel to the slope of the pipe.

With these measurements, the flow can be calculated as follows:

$$Q = \frac{1800\,AX}{\sqrt{Y}}$$

where:

Q = flow in gallons per minute

A = cross-sectional area of the fluid in the pipe in square feet

X = the distance in feet, measured parallel to the pipe, between the end of the pipe and the vertical gauge

Y = the vertical distance in feet from the water surface at the end of the pipe to the intersection of the vertical gauge and the falling water surface.

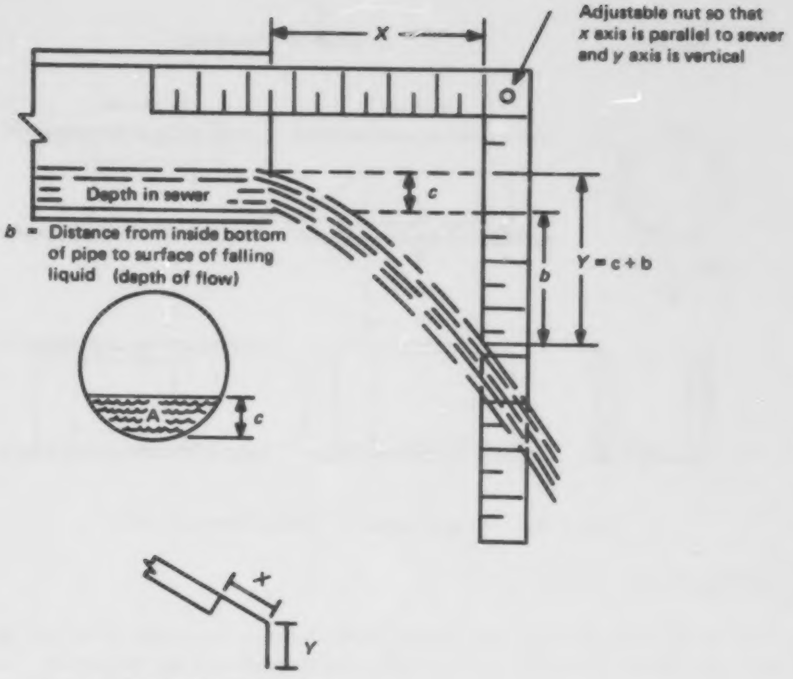

Adjustable nut so that
x axis is parallel to sewer
and y axis is vertical
X
c
Depth in sewer
b = Distance from inside bottom
of pipe to surface of falling
liquid (depth of flow)
b
Y = c + b
A
c
X
Y
For sloped sewers or pipes

Figure II-7. Measurement of *X* and *Y* dimensions for open-pipe flow measurements.

To determine the cross sectional area, *A*:

1. Cylindrical pipe, refer to table II-2.
2. Rectangular or other configuration, refer to the section Flows in Open Channels.

Measuring Devices

A variety of devices are available for measuring open-end discharges.[1] These are constructed for direct attachment to the end of a pipe and are designed and calibrated to enable direct visual observation of flows. Automatic recording instruments are available as accessories for many of these commercial models. Alternatively, open channel extensions may be constructed and fitted with a weir, Parshall flume, or Palmer-Bowlus flume.

PIPES UNDER PRESSURE

Flow measurement in pressurized pipes necessitates installation of in-line meters. Most meters rely either upon rotating indicators to detect flow or upon orifices to detect pressure differentials across a constricted section of pipe. Although these devices are satisfactory for metering water flows, the normally high concentration of particulates in food processing wastewaters generally precludes their use for metering waste streams. However, one type of in-line meter, the electromagnetic flow meter, is useful for this purpose.

The electromagnetic flow meter is a relatively recent development in flow measuring devices. The operating principle of this meter is based upon Faraday's law of electromagnetic induction, which (simply stated) says:

> "The voltage induced across any conductor as it moves at right angles through a magnetic field is proportional to the velocity of that conductor."

Figure II-8 illustrates how this principle has been applied to the flow meter. A uniform magnetic field is created around a section of pipe with electromagnets. As the fluid conductor (water) moves through the magnetic field surrounding the pipe, a voltage is generated at the electrodes. The magnitude of this induced voltage is measured by a suitable instrument and converted to measurements of flow.

The operation of an electromagnetic flow meter is not affected by changes in liquid viscosity, density, line pressure, presence of solids, or turbulence of flow. Furthermore, the inside diameter of the pipe is free from constrictions or protuberances which might impede the flow of fluid in the pipe. Flows in water pipes, hydraulic conveying systems and waste pumping lines can all be monitored with such meters without concern for loss of head, solids build-up, clogging, or other problems associated with the other types of meters. These features render this meter extremely attractive for use in fruit and vegetable processing plants.

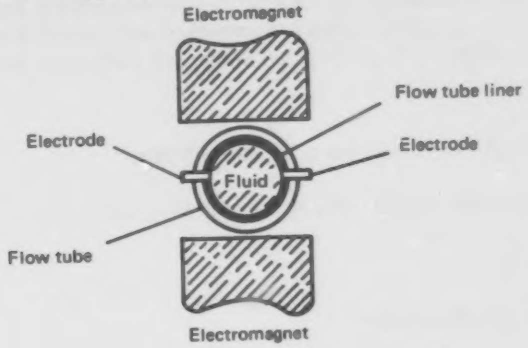


Figure II-8. Operating principle of the electromagnetic flow meter.

SAMPLING PROCEDURES

The type of information desired will dictate the method utilized for obtaining wastewater samples. Analysis of grab samples collected during the course of a day's operation will reveal temporary fluctuations in the physical and chemical characteristics of the waste, whereas the daily average values can be obtained with a minimum of analytical work from composite samples.

The type of sample, whether grab or composite, should also be selected on the basis of the stability of the constituent to be measured, and the degree of accuracy desired in the results. Below are listed some specific tests under the type of sample most suitable for its determination. However, most of these determinations can be made on either type of sample and in a routine testing program, this is frequently done.

Grab Sample	Composite Sample
pH	Biochemical Oxygen Demand
Total acidity	Chemical Oxygen Demand
Total alkalinity	Total solids
Chlorine residual	Suspended solids
Dissolved oxygen	Dissolved solids
Settleable solids	Ammonia nitrogen
	Orthophosphate phosphorus

Regardless of the method used, the importance of representative sampling cannot be overemphasized. Serious errors in waste load calculations will occur if appropriate precautions are not observed. For example, since heavy particles will rapidly settle to the bottom of a container, errors in solids concentrations may occur when water samples are transferred from one container to another. Therefore, the samples should be well-mixed whenever such transfers are made.

GRAB SAMPLES

Grab samples are individual portions of material taken from each collection point. For in-plant surveys, grab samples should be taken several times per shift. Hourly samples will yield a more complete profile of waste fluctuations occurring within each survey period. Fluctuations in characteristics between individual grab samples are expected and reflect normal variations caused by changes in raw product volume and quality, style of pack and other influencing factors which are discussed later.

The equipment required for taking grab samples are:

1. A one-gallon capacity pail (plastic or stainless steel).
2. A large funnel.
3. A container-carrying rack.
4. Containers.
5. A simple dipper, fashioned from an enamel-lined can attached to a long pole, will facilitate obtaining samples from difficult-to-reach areas.

An inexpensive and useful container for grab sample collection is a one-quart, wide-mouth plastic bottle or mason jar with a screw cap (available in most supermarkets and hardware stores). Wastewater samples collected for chlorine residual, hydrogen sulfide, dissolved oxygen, or phosphate determinations should be collected in screw-cap glass jars with airtight closures. These jars should be completely filled to avoid entrapment of air. Glass containers must be used for all samples which are to be analyzed for oil and grease.

Procedure

When collecting grab samples, the following precautions should be observed:

1. One to four quarts of sample should be taken at each sampling, the volume determined by the number of parameters which are to be recorded. Care should be exercised to insure that the samples are free of large pieces of suspended material, such as sticks, stems or other pieces of product which would normally be removed by an effluent screen. If large particles are unavoidable, wastewater samples should be passed through a 20-mesh (or equivalent) laboratory sieve prior to analysis.

2. When it is necessary to sample wastewater at different levels in a tank, a weighted bottle with a stopper in place may be lowered to the desired depth and the stopper removed by means of an attached string. The bottle should be held in place until bubbles cease to rise. For routine sampling from large storage tanks, selection of the proper depth should be made with care; skimming the liquid surface must be avoided. A sampling point of one-third to one-half of the liquid depth is recommended.

3. The discharge from pipes, weirs and flumes should be sampled in such a manner that turbulence in the sampling device does not concentrate the heavier solids at the bottom while floating away suspended matter. This can be avoided by collecting the sample without overflowing the pail or dipper.

4. The containers should be clearly labeled with sampling point, date and time of collection. Sampling points throughout the plant should be designated by a code (such as a letter) to identify the product being packed and by numbers to identify the sampling sites. A convenient way of labeling glass containers is to write directly on the surface with a felt-tip marking pen containing permanent ink (available from Esterbrook Pen Company, Carters Ink Company, and others). Masking tape may be affixed to plastic containers for labeling purposes.

COMPOSITE SAMPLES

A composite sample consists of measured portions, or aliquots, of wastewater collected at frequent regular intervals. The individual aliquots are combined into a single container to form the composite sample. The sampling may cover any convenient time period, such as a shift or a 24-hour operation. A composite sample has the disadvantage of not revealing fluctuations in waste characteristics which occur during the sampling period. However, this procedure is most convenient for determining the *average* characteristics of a waste stream over a period of time.

The equipment required for manually composited samples is identical to that used for obtaining grab samples. Additionally, a large collection container with a capacity of 2 to 3 gallons should be provided.

Procedure

If the rate of waste discharge is fairly constant, a composite sample may be made up of individual samples of the same volume, each collected in the manner described for taking grab samples. If, however, the rate of discharge varies, as is usually the case, a weighted (proportional) sample is of greater value.

To obtain a proportional composite sample, the rate of waste flow must be known and the individual aliquots constituting the composite sample should be proportional in volume to the rate of waste flow at the time the sample is collected. For example, if the rate of flow at one sampling time is 500 gpm, the sample at the time could be 50 ml or some multiple of that amount. If the rate of flow increases later to 1,000 gpm, the sample at that time would be 100 ml or some multiple of this amount. However, abnormal surges in the flow should be disregarded. The size of the individual portions should be such that the volume of the composite sample will be 1 to 2 gallons.

Automatic Composite Samplers

A wide variety of automatic sampling devices are commercially available. These devices collect and composite wastewater samples over a predetermined period, thereby releasing an individual from the responsibility of having to manually obtain periodic samples. Such samplers are available for almost all situations, whether samples are to be drawn from a sump or tank, a flume or a pipe.

Current prices range from about $300 for a simple device to more than $3,000 for a refrigerated proportional sampler. Selection of a suitable model will be determined by the requirements of each situation. Manufacturers should be consulted for recommendations. When selecting a sampling device, the following points should be considered:

1. Will the sampler obtain representative samples? Be certain there are no hoses or tubing which will contain a static volume of wastewater that will later be added to the composite sample.

2. Be certain that all valves and/or other orifices are of sufficient size to preclude clogging by particulate matter which might be present in the waste stream. This factor is important in sampling fruit and vegetable wastes.

3. If the volume of liquid flowing in the waste stream varies frequently, does the sampler take proportional samples? Or, can the sampler be readily adapted to do so? Can the sampler be used at the low flow rates sometimes encountered in fruit and vegetable processing?

4. Does the unit provide refrigerated storage for the composite? If not, will the sampler readily deliver aliquots of wastewater to a collecting container placed in a refrigerator? (See the following section, Sample Preservation.)

5. Is the construction of the sampler such that the device can be readily cleaned without tedious dismantling? Periodic cleaning is especially important for pipes, tubing and other parts which come in contact with the liquid waste.

The less expensive composite samplers collect aliquots on a fixed time-fixed volume ($T_F V_F$) basis. Although this procedure is satisfactory for constant flows, $T_F V_F$ samples will yield only approximations for most food processing wastewater streams. However, these samplers are portable and convenient for use in in-plant surveys. Representative analytical results can only be obtained with flow-proportional composite samples. Two basic types of automatic samplers are available for collecting such samples, as described below.

Some flow-proportional samplers are designed to collect aliquots of varying volume at fixed time intervals ($T_F V_V$). The volume of each aliquot is determined by the flow at the time of collection. $T_F V_V$ samples are satisfactory for all moderately variable flows.

The greatest accuracy is obtained by analyzing samples which have been collected on a "per unit flow" basis ($T_V V_F$). Automatic samplers designed to composite samples on this basis require flow measuring devices capable of signaling the sampler at appropriate intervals, generally whenever each 1,000 gallons of wastewater has flowed through the meter. Thus, each aliquot is a fixed volume and represents a unit volume of wastewater. This method is the only satisfactory one for highly variable flows and is recommended for routinely monitoring wastewater discharges.

SAMPLE PRESERVATION

Most food processing wastes are relatively unstable because bacterial growth and chemical reactions can cause significant changes in a short time. For example, samples stored for one day at room temperature may be 10 to 40 percent lower in BOD than the fresh waste. The rate of change is influenced by temperature, pH of the sample, and the concentration of dissolved components. Any attempt to inhibit bacterial growth by the addition of bacteriostatic agents may hasten chemical changes or alter some physical characteristic of the waste. Immediate analysis is the best insurance against significant errors in the use of grab samples. However, this is not always practical, especially when samples are collected from points quite distant from the laboratory. Furthermore, composite samples must often be stored for as long as 24 hours. To minimize compositional alterations in these samples, some means of preservation must be used.[1, 3]

PRESERVING SAMPLES IN THE FIELD

When collecting samples in the field, delays are often encountered before the samples can be delivered to the laboratory. Under such circumstances, the samples should be stored in ice. Insulated ice chests are convenient for this purpose, providing an inexpensive and portable means for assuring minimal changes in the waste. Collection containers should be sealed, placed into the ice chests and packed with crushed ice. Samples can be held in such a manner for several hours in even the warmest climates. Storage duration can be prolonged by periodically draining the chest and repacking it with more ice. Care should be exercised to assure that water from the melting ice does not enter the containers, thereby diluting the waste samples.

REFRIGERATION

Refrigeration at 4° C (39° F) is the preferred and most common method for temporary preservation of wastewater samples, especially for storage of composite samples during the period of collection. Refrigeration retards bacterial growth, chemical reactions and physical changes. In situations where the interval between sample collection and analysis is long enough to produce changes in the physical and chemical characteristics, the preservation practices listed in EPA's manual entitled *Methods for Chemical Analysis of Water and Waste*[3] are recommended.

FREEZING AND THERMAL PROCESSING

In situations where analysis of wastewater samples will be unavoidably delayed, the samples may be preserved by freezing or thermal processing. Samples for freezing should be placed in flexible containers with sufficient space left in the containers to allow for ice expansion. Thermal processed samples should be placed in enamel-lined cans with a 1/2-inch headspace provided and processed for 25 minutes at 240° F (or equivalent). However, significant changes will occur in the chemical and physical characteristics of samples so preserved. Therefore, these procedures should be used only in emergencies; the analytical results should be considered as approximations.

ANALYTICAL PROGRAM

Companies implementing either in-plant survey or wastewater discharge monitoring programs must decide the most cost-effective procedure for developing the required analytical data. Such data may be obtained through contractual services of commercial laboratories or by establishing in-house analytical capabilities. The economics of either will be primarily dictated by the frequency of sampling, the number of samples, and the number of parameters which will be evaluated for each sample.

COMMERCIAL LABORATORIES

For monitoring programs requiring minimal data accumulation, commercial laboratories generally offer the most economical and convenient means to obtain necessary information. Laboratories with capabilities for analyzing wastewater samples are numerous and geographically widespread. Typical costs for measuring significant food processing wastewater parameters are listed in table II-3.

Table II-3.—*Commercial laboratory fees for significant food processing wastewater parameters*[a]

Parameter	Cost/sample
Biochemical Oxygen Demand (BOD_5)	$10.00 - 20.00
Chemical Oxygen Demand (COD)	7.50 - 10.00
pH	2.00 - 5.00
Settleable solids	3.00 - 5.00
Suspended solids	5.00
Total dissolved solids	5.00
Total solids	5.00

[a] Based on survey of several laboratories. Discounts are generally available for multiple samples.

When selecting a commercial laboratory, consideration should be given to the following:

1. Recognition by regulatory agencies. Several states have certification programs for commercial laboratories. Where this is the case, certified laboratories should be employed (check with the local agency for a list of such laboratories). In areas where no certification program exists, ascertain that the selected laboratory follows recognized analytical procedures. See Appendix A.

2. Convenience of sample delivery. Although it would be ideal to have a commercial laboratory in sufficiently close proximity to enable personal delivery of all samples, this situation is infrequently encountered. Normally, some means of shipment must be arranged. It is important that minimal delays occur in transit, preferably no more than 24 hours. Bus lines provide convenient intrastate and intercity sample transportation.

3. Rapid "turn-around." The selected laboratory should assure that samples will be quickly analyzed upon receipt and the results reported immediately.

4. Other services and amenities. Most laboratories will provide detailed instructions on sample preparation and shipment. Some provide specially designed containers to insure against breakage and resultant loss of sample. Reputable laboratories willingly provide advice in selecting appropriate analyses and are cognizant of the need to preserve biodegradable samples.

IN-HOUSE CAPABILITIES

Analytical capabilities at the fruit and vegetable processing plant offer the major advantage of rapid results, an essential factor for controlling treatment systems and wastewater discharges. The costs for establishing this capability will vary widely. Major influencing factors are (1) availability of a technician(s) capable of performing the analyses, (2) the type of tests which are desired, (3) the availability of basic analytical equipment, and (4) the availability of a sufficiently spacious working area with appropriate laboratory fixtures.

Analytical Equipment

The analytical equipment required for in-house analyses will be determined by the parameters to be measured. The equipment and apparatus required for each test are described in References 2, 3, and 4. However, a basic need for all quantitative analyses is an analytical balance capable of weighing to 0.1 mg.

Laboratory Facilities

The work area for laboratory analyses should be in a well-ventilated room. Minimum furniture requirements for performing rudimentary analyses and physical measurements are (1) a sink, preferably one specifically designed for laboratory use (or an old fashioned stone laundry tub) equipped with PVC or glass traps resistant to acids; (2) a laboratory bench with a chemical resistant surface and at least 4-feet long; and (3) an under-counter cabinet and/or a set of drawers. Minimum requirements for utilities are hot and cold tap water and electricity (110 - 120 V). When capabilities for additional analyses are desired, additional pieces of furniture (such as increased bench space, additional cabinets and drawers, and a laboratory fume hood) will be required with additional utilities (such as air, vacuum and gas lines) desirable. The basic laboratory should also be equipped with a refrigerator for storing wastewater samples and a distilled or demineralized water source (purchased bottled water will suffice when needs are minimal).

MAJOR WASTEWATER PARAMETERS

The major wastewater parameters for the fruit and vegetable processing industry are categorized in table II-4. The significance of each is discussed in volume 1. Details of EPA-approved test procedures may be found in the EPA's *Methods for Chemical Analysis of Water and Wastes*[3] and in *Standard Methods for the Examination of Water and Wastewater*[4] published by the American Public Health Association (also see Appendix A of this volume).

Table II-4.—*Major wastewater parameters (fruit and vegetable processing industry)*

Basic	Significant	Desirable/optional
pH	BOD_5	Acidity & alkalinity
Temperature	COD	Chlorides
Settleable solids	Dissolved oxygen	Nitrogen, organic
	Suspended solids	Oil & grease
	Total dissolved solids	Phosphorus, total
	Total solids	Turbidity

DATA ANALYSIS

Permanent records should be maintained for all information developed during in-plant surveys and wastewater discharge monitoring programs, preferably on a daily basis. Information noted in the records should include date, time of sampling, sample identification, flow, summary of analytical results, and production data. Analytical worksheets should be kept on file in the event that questionable results occur. The use of bound notebooks with tear-out carbon inserts avoids the loss of data or questions arising from "altered" data. Information developed during well planned surveys will identify the major water-consuming and pollutant-generating operations. This information is essential for implementing in-plant pollution controls, such as water conservation techniques and process modifications. Surveys conducted subsequent to process changes will enable evaluation of the effectiveness of those changes and their future operational control.

The most important information to be obtained from a waste survey is the identification of waste load variability and peak loadings which are associated with all of the operations at the plant. This information is vital to the designing of successful waste treatment facilities. Therefore, survey programs implemented to accumulate these data must be conducted through a minimum of one entire processing season.

Data developed through monitoring programs can be used to establish raw waste loads (that is, the quantity of pollutants per ton of raw product) for each commodity and commodity-mix processed at the plant. The raw waste load (RWL) can be calculated as follows:

$$\text{RWL (pounds/ton)} = \frac{\text{total flow (gal)} \times 8.34 \times \text{pollutant concentration (mg/l)}}{1{,}000{,}000 \times \text{tons of raw product}}$$

This calculation should be made for at least BOD and/or COD and total suspended solids using the daily average concentrations. The results should be recorded in the permanent log. If several samples are collected and separately analyzed during each day, calculation of the range (highest and lowest values) will be useful.

By plotting RWL's and pollutant concentrations on a daily basis, waste profiles can be developed for the plant. Such profiles are useful for establishing normal variabilities which can be expected in the processing wastewaters. Thus, "unusual" results will generally indicate a need for investigation of cause and possible remedial action.

Chapter III

FACTORS INFLUENCING WASTE GENERATION

Factors which affect the generation of wastes in processing fruits and vegetables are considered in this section under several overlapping headings. Inplant survey programs should be designed to elicit these data for each plant.

COMMODITY

On the average, wide ranges of discharged water flows and of generated pounds of pollutants are found per ton of different commodities. Examples are plotted in figures III-1 (wastewater) and III-2 (BOD). Other data are found in table III-1. Although the average differences are large and significant, the variability among plants processing the same commodity is much greater than the variability of the averages from one commodity to another. This is shown by the probability limits of the data, the upper and lower values expected to enclose the per ton generation of 95% of the plants processing each commodity. In spite of the large average differences, the distributions of all of the commodities overlap one another. In most instances, generation of wastes varies more than twenty-fold within commodities and is sometimes much more variable than this. Some of the reasons for the wide variability within commodities are the raw product condition, method of harvest and transport, and preparation procedures and equipment.

RAW PRODUCT CONDITION

It is widely understood in the industry that the quality of the raw commodity, as influenced by maturity, injury, harvest conditions, and weather, affects the generation of wastes from processing. However, quantifications of this effect are sparse. No studies have yet been identified which assess the quality of the raw commodity. A measure of the effect of commodity quality upon generation of wastes is found in the records of BOD generation at a tomato plant. Average amounts were 6.0, 5.5 and 11.9 pounds of BOD per ton of tomatoes in 3 consecutive years. The generation doubled in the absence of plant changes that could account for the differences. Similarly, in 2-year records, the BOD generated per ton varied two-fold between years at both an apricot and a pea plant. Suspended solids per ton varied more than four-fold at the apricot plant and three-fold at both the pea and a lima plant. In all these cases, there were no implant changes that would explain the differences. Variations in the condition of the raw product may have accounted for them.

HARVEST AND TRANSPORT

The methods and conditions of harvesting and transporting raw commodities affect the generation of waste. Machine harvesting and subsequent transportation of tomatoes may double the amount of visible damage and may increase field soil from a trace to as much as 2% of the weight of product. Mechanical harvesting also increases the field soil on snap beans and bruises on tree fruits. Transportation of various commodities in bulk containers may increase damage by pressure. In addition to the direct wastes from the soil and from leaching and culling damaged product, more water is needed for washing away the soil. Therefore, both the volume and the strength of the wastewater are affected.

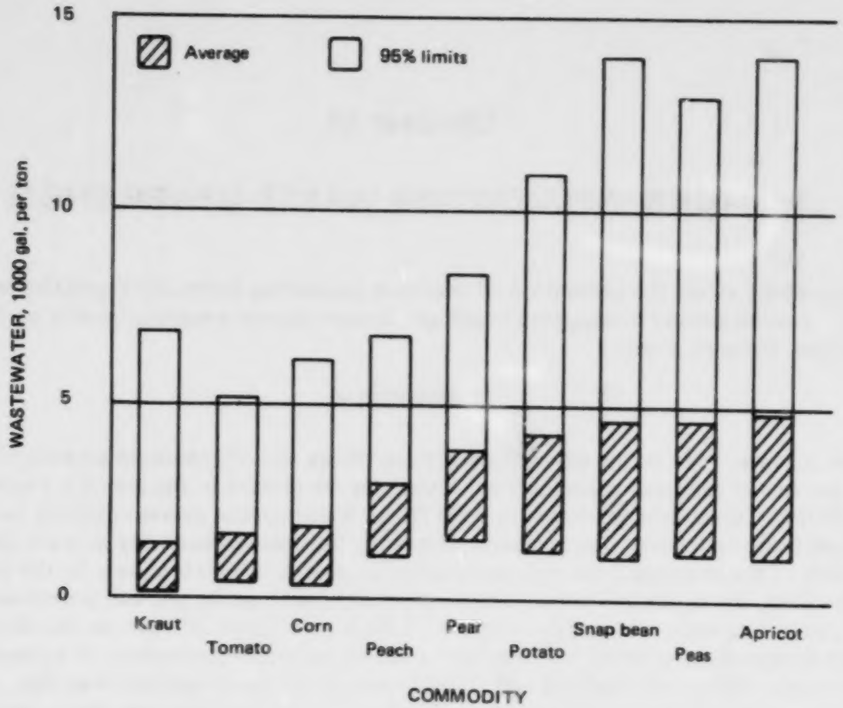


Figure III-1. Generated wastewater, average and 95% limits.

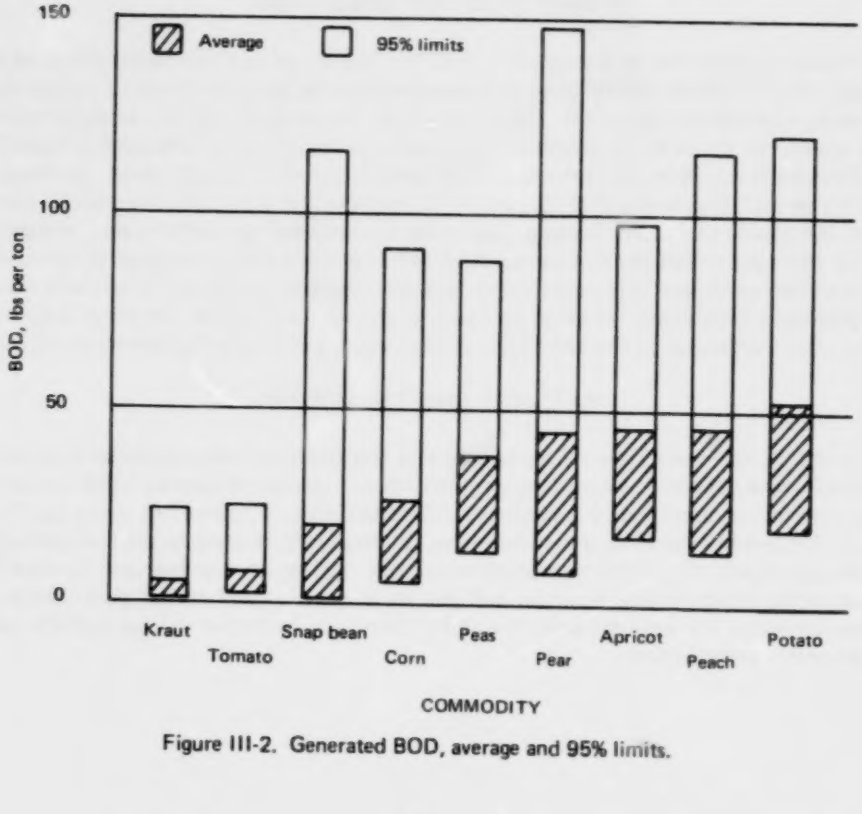


Figure III-2. Generated BOD, average and 95% limits.

Table III-1.—*Wastewater and generated pollution loads by commodity*

	Wastewater 1000 gallons/ton			BOD pounds/ton			TSS pounds/ton			Temp.	pH
	ave	95% limits		ave	95% limits		ave	95% limits		ave	ave
Apple	3.2	.2	17	22	4.4	64	6.3	.5	30	54	5.6
Apricot	4.9	1.1	14	45	17	98	9.9	4.0	22	76	8.0
Asparagus	8.6	1.4	31	5	.6	26	7.5	4	13		
Dry bean	9.8	1.1	44	75	16	238	59	(2	130)[a]		6.8
Snap bean	4.7	1.1	14	20	.7	116	7.0	.3	63	70	7.3
Beet	4.0	.8	12	44	5	217	26	2	116		7.9
Berry	3.5	.4	16	24	5.2	77	16	(1	57)[a]		
Broccoli	8.8	1.6	32	16	2.1	54					
Cauliflower	11	(1.7	23)[a]	18	(2	49)[a]					
Carrot	4.0	.8	13	31	9.6	80	17	2.0	72	63	8.7
Cherry	4.8	.4	27	15	2.4	75	.8	(.5	1)[a]		
Citrus	4.3	.4	16	16	(1	45)[a]	6.0	(2	10)[a]	79	6.5
Corn	1.9	.3	6.2	27	4.8	91	12	2.1	44	77	5.6
Grape	2.8	.3	13								
Lima	7.3	1.4	24	58	6.0	240	50	2.7	332		
Mushroom	9.6	1.7	33	20	8.8	40	10	4.2	22		
Okra	5.0	1.3	15								
Onion	6.8	(.2	17)[a]								
Pea	4.7	1.2	13	38	13	88	12	1.3	67	70	6.0
Peach	3.0	1.1	6.8	45	13	116	9.1	1.8	30	72	9.6
Pear	3.9	1.5	8.4	44	8.6	147	8.7	1.7	29		7.0
Peppers	4.6	.9	16	32	(5	50)[a]	58	(1	170)[a]		
Pickle	4.6	.8	19								
Pineapple	1.7			16	7.4	31	9.9	3.5	24	92	6.8
Plum	4.9	.4	23	11	(3	19)[a]	4.4	(.3	11)[a]		6.8
Potato	4.3	1.2	11	52	19	120	44	3.8	250		
Pumpkin	2.9	.4	11	32	9.2	87	6.7	(2	12)[a]		6.3
Sauerkraut	1.4	.1	6.9	6.0	.9	24	.6			65	6.4
Spinach	7.3	1.5	23	13	3.5	37	4.6	1.7	11		
Sprouts	10.1	(4.8	20)[a]	25	(5	75)[a]					
Squash	6.0	1.1	22	20			14				
Sweet potato	4.0	.3	23	60	24	130	34				
Tomato	1.7	.4	5.2	8.6	2.0	26	8.4	.3	66	79	7.9
Turnip	7.3	2.4	18								

[a] "Limits" in parentheses are reported maxima and minima.

PREPARATION PROCEDURES AND EQUIPMENT

PRODUCT STYLE

The kind of products made from a given commodity influences the amount of wastewater and the generation of pollutants. An example of this influence is found in figure III-3, in which the generation of BOD is compared to the percentage of peeled style tomatoes; on the average, the more peeling, the more BOD. The relationship is highly significant in spite of the wide probability limits. In a recent study, slicing apples, slicing snap beans, peeling tomatoes, and

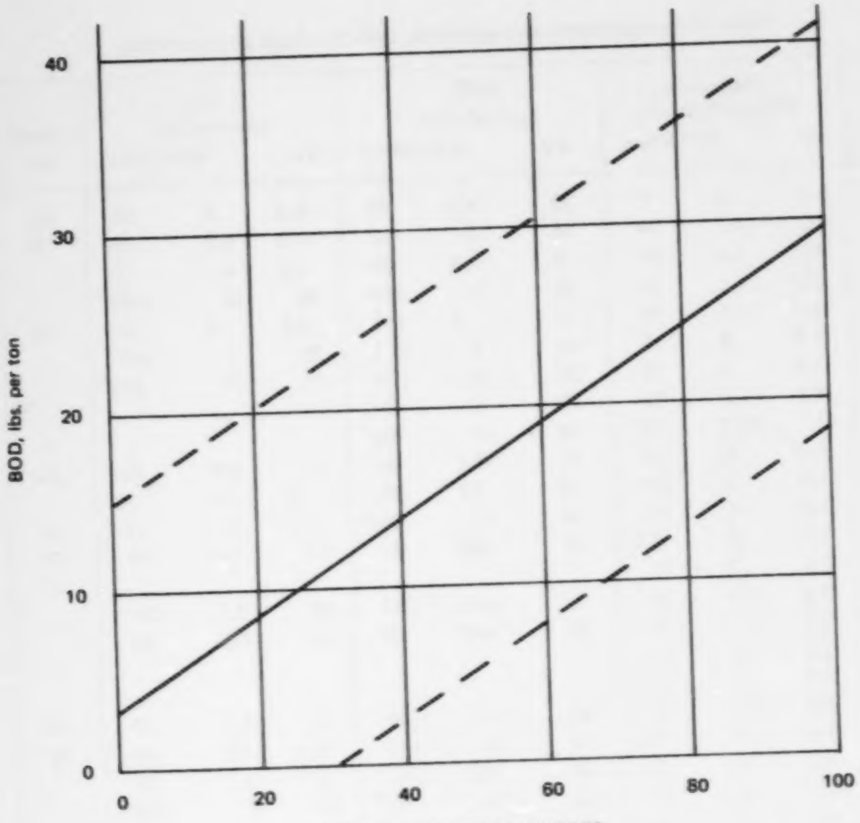


Figure III-3. Tomatoes, peeling and BOD generation, with 95% limits.[5]

cutting beets and carrots generated significantly greater amounts of BOD, compared to other styles. In data from eight commodities, 21% of the variability among plants in the generation of BOD was accounted for by style. Extra operations added to the preparation steps, such as slicing, require extra water. Cooking and cooling canned products takes more water on the average than condensing for frozen products. On the other hand, frozen but not canned corn must be blanched, requiring more water and generating additional pollutants.

TYPES OF EQUIPMENT

Most of the steps in preparing foods for preservation can be done in more than one way and the difference in the generation of wastes is one of several factors considered in choosing a preparation method. Peeling and blanching are such steps. For those commodities which are peeled, from 30 to 60% of the total plant pollutant load is commonly contributed by peeling; for blanched commodities, from 10 to 60% of the load commonly comes from blanching. Low-waste-producing equipment has been developed for both procedures. Dry caustic peeling is reported to reduce the wastewater flow from the peeling operation by 80 to 90% and the pollutant load from peeling by 60 to 90% in processing potatoes, beets, and peaches. The dry caustic equipment is more expensive than conventional peelers. Modified blanching methods have reduced the blanch wastewater by two-thirds to almost 100% and the generation of pollutants in the blanching operation by about the same for peas, limas, corn, snap beans, and spinach. However, higher costs and product loss can be problems. In a recent industry study, about 12% of the BOD generation and 9% of the suspended solids generation at apple, beet, carrot, pear, and tomato plants were associated with the type of peeling equipment in use.[5]

Other differences in preparation equipment go with the style of the product. For example, pitters may or may not be used in processing such fruits as cherries, plums, and olives; a variety of cutters and slicers are used in some plants for peaches, pears, apples, snap beans, spinach, root crops, and other commodities; size graders are needed for efficient preparation of some commodities; specific gravity quality graders may be used on peas and limas; and mechanical corers are needed for some styles of apples. All of these alternative preparation steps use water and generate pollutants to some degree.

WATER USE

Water is both recycled within the same piece of equipment (for example, returned from the end to the beginning of a flume) and reused from one piece of equipment to another, typically from a later to an earlier step in the preparation process. Cooling, chlorinating, or other renovation procedures may occur between uses. Fruit and vegetable processors are estimated to get 64% of their water from such reuse (180 billion gallons from 280 billion gallons per year of gross applied water). The percentage of reused water varies among plants from little or none to more than 90% and tends to increase on the average with increasing plant size. About 40% of the plants separate their relatively clean wastewater (typically cooling or condensing water) from that with a higher pollutant load and dispose of the two streams separately. The clean water is also a source of water for reuse.

Water is commonly used to transport the product between preparation steps. Water transport is both economical and advantageous in maintaining sanitation. The amount of water transportation varies widely among plants and somewhat, on the average, among commodities. The contribution of water transportation to the pollutant load depends on the stage in preparation at which it occurs. Among commodities with a fairly high degree of exposure to leaching from this source are asparagus, snap beans, broccoli, cauliflower, carrots, mushrooms, okra, pears, potatoes, and soft squash; among those with a low degree of exposure are berries, grapes, pickles, pineapple, plums, pumpkin and sauerkraut.

The quantity of organics leached from the product is a function of the duration of immersion and the size of the food particle. Figure III-4 shows this for timed immersions of pieces of pears from unpeeled halves to diced.[6] The measured concentrations are of total oxygen demand, proportional to BOD in this instance. The pollutant strength increases sharply with both immersion time and decreasing size of cut.

Solid residuals from food processing (culls, peels, pits, etc.) may be removed from the plant in a water stream or by a dry transportation method. The degree of water conveyance of residuals varies widely among plants processing the same commodity but fairly consistently among commodities on the average. The most solid residuals removed have been reported in apricot, asparagus, dry bean, berry, pepper, pickle, potato, pumpkin, soft squash and turnip plants; the least in apple, cauliflower, citrus, corn, mushroom, okra, pineapple and sauerkraut plants.

Leaching from solid residuals would be similar to that from the food product, a function of time and particle size. However, water transportation of either the food or the residuals explains only a tiny fraction of the plant to plant differences in pollutant generation. Industry data indicate that only 1% of the variation in wastewater volume is associated with either factor; and 4% of the variation in BOD generation is associated with water transport of the product.[7]

PERCENT OF USED CAPACITY

Food processors commonly use about 80% of a plant's design capacity, sometimes much less. The unused capacity is needed for glut conditions within a season and for bumper crops which could occur any year. The proportion of the capacity used varies widely from day to day within a plant. Both wastewater flow and BOD generation per ton increase as the proportion used decreases.

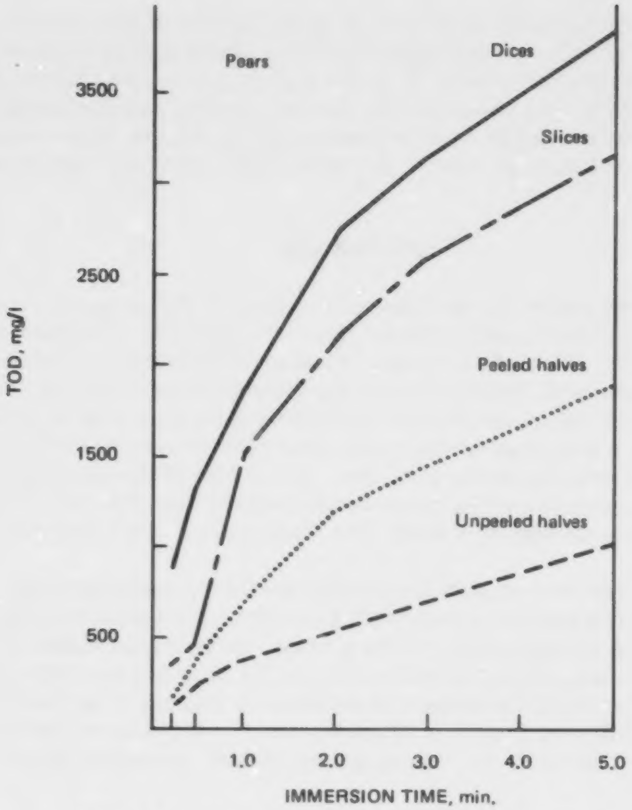


Figure III-4. Effect of immersion and cutting on pollution.[6]

One reason for this strong negative relationship is that the flow of water cannot be reduced in some equipment to match a reduced flow of product; and so, more water leaches more BOD. Other factors could be partly responsible. For example, larger tonnages may force a shift in the proportions of product styles because of equipment bottlenecks.

HOUSEKEEPING

Many operations in food processing which are incidental to the principal steps in preparing the product affect both the quantity and the strength of wastewater. Some of these practices are described here briefly and discussed in detail in the following chapter.

WATER USE

Water running in unused equipment is a source of waste. Examples are cleanup hoses between periods of use, and flumes, washers, or graders which are empty of product.

CLEANUP

Sweeping (instead of hosing) and dry conveying of solid residuals save water and reduce pollutant generation. High pressure-low volume systems permit plant cleaning with efficient water use. The continuous application of chlorinated water to belts and other suitable equipment makes subsequent cleanup easier and more efficient. Clean-in-place systems can be designed to clean pipes, tanks, and other equipment automatically and without wasting water. Prompt removal of residues preventing a buildup of food deposits where water is running avoids excessive leaching.

Food processing demands sanitation. Whatever is done to conserve water and abate pollution takes a second place to maintaining sanitary conditions in a food plant and its equipment.

SPILLAGE

Spilled products, especially juiced commodities and syrup, are a strong source of BOD and suspended solids. If spills are unavoidable, the product should at least be kept out of the wastewater stream.

Chapter IV

IN-PLANT MODIFICATIONS AND EFFECTS

A. WATER CONSERVATION TECHNIQUES

Today, as always before, the fruit and vegetable processing industry is entirely dependent on an adequate supply of good quality water. Automation cannot completely replace the need for water. There are no mechanical or chemical substitutes for its use in certain operations.

Because of increased concern about chemical and biological contaminants on foods, and more rigid definitions of cleanliness, the effective use of water is more important today than ever before. In 1974 the canning and freezing industry processed some 35 million tons of fruits and vegetables. Over 100 billion gallons of water were discharged by the industry, with some 180 billion gallons of water being reused.

Today water is becoming an expensive commodity and it must be used efficiently and effectively. Water and waste costs may appear to be a small percentage of gross sales, but become significant when compared to the small profit obtained from sales. As a matter of economic necessity coupled with recognition of responsibility in matters of public concern, the food industry is giving increasing emphasis to water conservation and stream pollution abatement.

Historically, the reuse of water in the food industry was discouraged because of the problem of bacterial contamination. Prior to the development of effective water chlorination procedures, any reuse of water in contact with the product was considered to be hazardous. Even now, the recovery of water from one operation for reuse in the same or other operation, will require consideration of the effect of this water-saving procedure on the quality of the final product, on general sanitation of the plant, and, especially, consideration of the effect on the sanitary condition of the unit operation in which the water is to be reused. Indiscriminate reuse of water can result in unexpected and undersirable conditions. Where chlorination of the reused water is relied upon to prevent bacteriological problems, the capabilities and limitations of chlorine as a germicide must be understood.

Water reclaimed for use in contact with the food product in its final stages of preparation must be low in total bacteria count, free of microorganisms having public health significance, and free of materials which could constitute adulteration of the product. In flumes for converying and preliminary washing of raw unpeeled or uncut products (such as whole pumpkins, beets, asparagus, whole fruits, etc.), water of lower quality, with regard to bacterial count, may be used. In the past, it was always the practice that partially or finally-prepared products such as washed or blanched peas, beans, asparagus, cut fruits, etc., should be conveyed or washed in fresh water. Today there are necessary and desirable exceptions to this general rule.

The economics of food processing have brought about development and widespread use of bulk-handling methods in preparing foods for canning and freezing. Within the plant, bulk-handling consists of hydraulic pumps for receiving raw foods and hydraulic systems for conveying foods to and from operations which prepare them for final processing. The excessive water demand of these hydraulic systems creates situations of concern to industry and the public in areas where water shortages exist. An allied concern in all areas of the nation is the necessity to treat the correspondingly large volumes of fluid wastes.

GUIDELINES FOR WATER USE

The principal conditions governing the use of reclaimed waters in contact with food products are the following:

1. That the water be free of microorganisms of public health significance.
2. That the water contain no chemicals in concentrations toxic or otherwise harmful to man.
3. That the water be free of any materials or compounds which could impart discoloration, off-flavor, or off-odor to the product or otherwise adversely affect its quality.
4. That the chemical and physical quality of the water be acceptable for its intended use.

Compliance of reused water with these conditions would not always mean that it meets the standards for potable water as defined by proposed drinking water standards (PL92-523). Because of the economic infeasibility, impracticality from an operational standpoint, and the lack of significant need for one-pass use of fresh water at all points in food canning, the National Canners Association objected to Section 128.07 of the Food and Drug Administration's proposed "Good Manufacturing Practice" regulations (21CFR 128 April 1974). Section 128.7 of the draft regulations included this statement:

> "Water used for washing, rinsing, or conveying food products shall be of potable quality and shall not be recirculated unless suitably treated to assure its potability."

The Association filed the following statement in reference to the above proposed regulation:

> "Water used in the washing of raw products is in many cases, recycled and chlorinated but it is far from potable in that it is not drinkable. The product as it leaves this water is cleaner than when it entered, which is the desired result. The same thing is true of the counterflow systems for using water throughout a cannery."

A counter proposal was offered and a compromise reached for the reuse of water. The current regulation now states:

> "Raw materials shall be washed or cleaned as required to remove soil or other contamination. Water used for washing, rinsing or conveying of food products shall be of adequate quality, and water shall not be reused for washing, rinsing or conveying products in a manner that may result in contamination of food products."

The Association believes that this compromise will allow a continuation of water conservation practices now in use which have been shown to have no adverse effect on the quality and wholesomeness of the finished product.

BENEFICIAL RESULTS FROM WATER CONSERVATION

Water recycling is beneficial for the following reasons:

1. Water is no longer a free commodity nor is it available in unlimited quantities.
2. There are economic considerations in the purchase of water and in the disposal of water.
3. Reductions in the volume of water used result in corresponding reductions in the volume of wastewater to be treated.

In some instances the total organic load may not be significantly reduced by water conservation. However, the containment of the organic load in fewer gallons of water will result in significant advantages such as:

1. Hydraulic overloads on treatment systems can be alleviated.
2. Treatment of concentrated wastewaters is more economical and efficient than the treatment of dilute wastewaters.
3. By increasing the concentration of organic matter in water, the potential for recovery or by-product utilization is enhanced.

THE COST OF WATER

The cost of water provided by a municipal system may vary from 15 cents to $2.50 per thousand gallons. In some areas where water is least expensive, it is generally of high quality, requires minimal treatment and minimal pumping. The higher costs for water are usually associated with poorer quality water which has to have extensive treatment and must be transported over long distances.

Often it is suggested that a company should drill its own well. This may or may not be a good suggestion. It depends on whether or not one is fortunate to obtain water at a reasonable depth which is also adequate in quantity and quality. The following is one example of costs associated with obtaining water from a well. Assume that the well delivers 500 gallons per minute and the first cost for the drilling, casing, pump, distribution system and controls is $40,000. If consumptive use is 400 gallons per minute and it is in operation for 8 hours and 200 days per year, some 40 million gallons of water per year will be withdrawn. With a 10-year straight line depreciation, the cost will be $4,000 or 10 cents per 1,000 gallons. Maintenance is usually more than anticipated and involves replacement of casing, replacement of screens and replacement of pump impellers. If $2,000 is allocated for this purpose, then maintenance will be 5 cents per 1,000 gallons. The electrical costs will be $1,470 per year of 3.7 cents per 1,000 gallons. Interest charges are calculated at 9 percent or 9 cents per 1,000 gallons. The total costs of obtaining water are tabulated as follows:

Depreciation	10¢
Maintenance	5
Power	3.7
Interest	9
Taxes, insurance & misc.	1
Per thousand gallons:	28.7¢

Actual costs may be less or may be more than cited in this example. The purpose is to illustrate that the cost of water can be expensive and should be considered in any water savings program.

PRODUCT WASHING AND RINSING

One of the principal uses of water in processing fruits and vegetables for canning or freezing is cleaning the raw commodities. Several washing and rinsing operations are generally provided to remove such materials as:

1. Microorganisms, especially mold and spoilage bacteria.
2. Soil.

3. Insect eggs and fragments.

4. Chemical residues, such as insecticidal dusts and sprays.

5. Organic debris, such as leaves and stems or product fragments.

6. Peel, especially following chemical peelers.

The volume of water used for washing varies widely, not only from one commodity to another, but also within each commodity from one processing plant to another. Some reported quantities of water used (gallons per raw ton or gallons per finished case) and characteristics of the wastewater produced by washing fruits and vegetables are summarized in table IV-1. Washing and rinsing operations are the major source of the hydraulic load associated with many products. The reduction of various contaminants by washing potatoes and tomatoes has been reported with the results being summarized in table IV-2.

TYPES OF WASHERS

Washing methods vary according to the product. Commonly used washers include:

1. Sprays positioned over belts, elevators, or other conveyors.

2. Flood-type washers, consisting of immersion or soak tanks in which the product is moved forward by angled sprays and/or by recirculated water. Flumes are also used for washing in a similar fashion.

3. Rotary or reel washers, consisting of sprays situated within a perforated metal or screen cylinder.

4. Brush washers, consisting of revolving brushes which scour the exposed product surface.

Two or more types of washers arranged in series are generally most effective; various combinations are used for most commodities.

Spray Washers

Sprays are used extensively for washing raw products. They may be used alone or in conjunction with other types of washers. The primary function of sprays is to apply water in such a manner as to physically and efficiently remove undesirable materials from the raw product. Therefore, how water is used (as dictated by the type of spray nozzles and their physical arrangement) is most important. The quantity of water used is of secondary importance.

The cleansing action of water is a function of the amount of energy imparted by the water on the raw product surface. Water impinging on a surface at a high velocity effects greater cleansing efficiencies than a large volume of water simply cascading onto the same surface. To obtain maximum cleansing efficiency of water used in spray washing equipment, careful consideration must be given to the choice and placement of spray nozzles.

1. Spray nozzles which deliver a small volume of water at high velocity are preferred. Nozzles which deliver a flat, fan-shaped spray are quite suitable and most effective when arranged in banks (see figure IV-1).

2. The nozzles should be of a design which minimizes clogging. This is especially important for sprays in recirculated water systems.

Table IV-1.–*Use of water in washing fruits and vegetables*[8]

Product	Function	Water used		Effluent load	
		gal/ton[a]	gal/case[a]	BOD lbs/ton[a]	SS lbs/ton[a]
Beans, green	wash		25.5		
Beets	primary wash flume	100		0.8	20.0
Carrots	primary wash flume	90		0.5	2.0
Corn	husked corn washer	103		2.5	1.0
	washer & silker	212		15.0	4.0
Cranberry	skimmer & washer	1440		36.5	15.0
Fruits	spray	385			
Peaches	spray	360 (gal/min)			
	lye peel rinser	707 (gal/min)			
	flume	1028 (gal/min)			
Peas	clipper mill & wash	706		12.0	5.5
	wash	432		4.0	0.5
Potatoes	spray	2500		20.0	30.0
	spray & soak	640		10.7	21.0
	peel & wash	468		2.2	2.2
	spray	960		5.1	2.7
" (dehydrated)	slicer-washer	1540		40.0	49.7
	primary wash flume	70		0.5	2.0
Tomatoes	wash	1320			
	rinse after dump	1186			
	lye peel removal	504			
	spray		712		
	lye peel rinse		1274		
	lye peel rinse		790		

[a] Ton of raw product or case of finished product.

3. The discharge rate of the selected nozzle must be adequate to meet the needs of each particular application. The nozzles must be operated within the design water pressure range. Operating pressures which are either too high or too low for the selected nozzles will decrease their effectiveness.

4. If the nozzles are positioned too high above the product, energy in the water will be partially dissipated and a less effective job of cleaning will result.

5. The nozzles must be spaced along each header so that the sprays do not overlap excessively, thereby resulting in excessive use of water.

6. The nozzles on the ends of each header should not be placed so close to the end as to cause waste of unused water along the sides of the washer.

Table IV-2.—*Effectiveness of washing in removing extraneous matter*[8]

Product	Function	Item	Reduction %
Potatoes (dehydrated)	presoak & wash	surface contamination	0.5-12
Tomatoes	wash	soil	33-80
		organic debris	30-64
		bacterial spores	6-79
		Drosophila eggs	10-70
		bacterial spores	75-95
		lactic bacteria	75-96
		mold	76-92
	chlorinated wash	bacteria	90
		spores	92

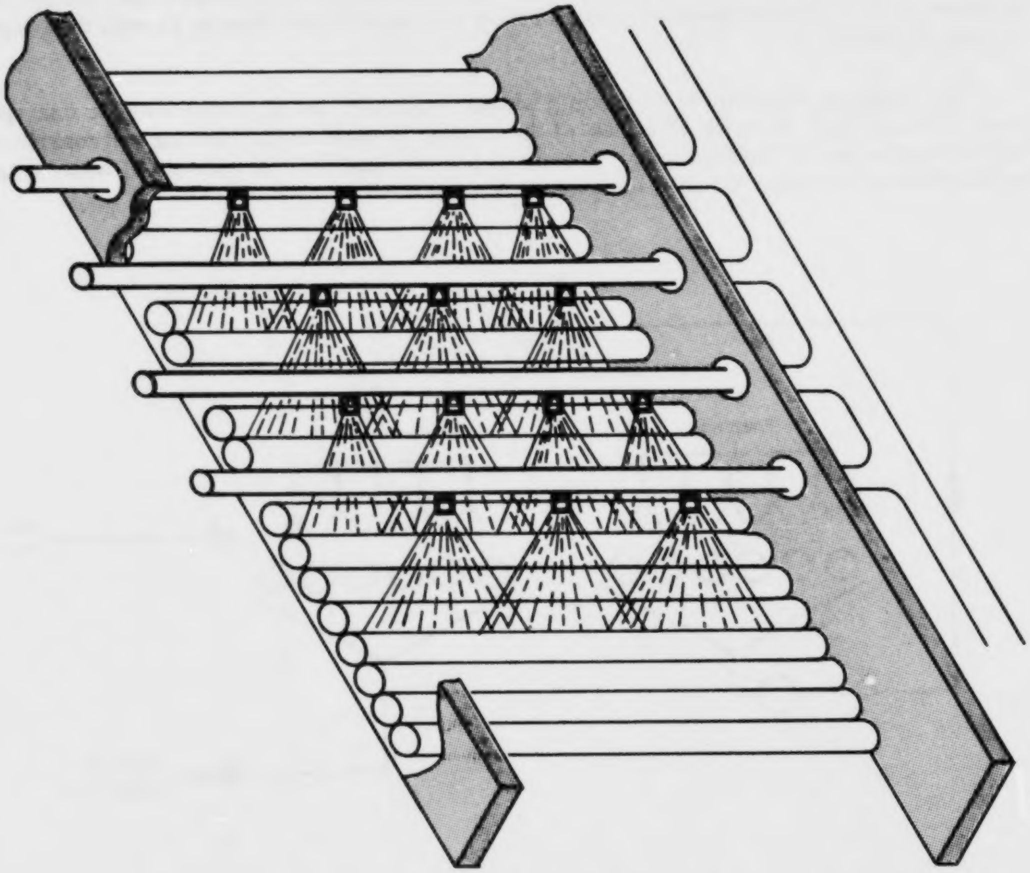


Figure IV-1. Recommended placement of sprays.

The type of conveyor used in spray washing equipment influences the cleansing efficiency. Roller conveyors are most effective. The revolving rollers turn the raw product, thereby exposing all surfaces to the sprays while permitting leaves, stems, and other debris to be flushed through the rollers. The conveyor of second choice is constructed of steel-mesh belting and the belting with the largest permissible openings should be used. Sprays should be positioned above and below the mesh belt. Use of solid belting should be avoided in spray washing equipment.

One of the problems in washing is the unavoidable variation in amount of product going over a line, depending on the schedule of deliveries from the field. Regardless of whether the line is loaded heavily or lightly, the washers operate with the same amount of water. Under constant conditions of water flow such as these, the cleanliness of the washed product is directly related to the quantity of product per unit volume of water. Wherever possible, the rate of product throughput should be as even as physically possible and held at that rate which yields maximum cleaning efficiency.

In some situations, consumption of water for spray washing and rinsing can be minimized by dividing the spray headers into two sets (see figure IV-2). Fresh water is used initially through the final set of nozzles. This rinse water can then be collected and pumped to the first set of nozzles, thereby reducing the total volume of water by a half. The wash water may be discharged as wastewater or may be collected and used for other purposes. This arrangement is especially effective when sprays are used in conjunction with other types of washers or as a final rinse prior to canning or freezing. It may be necessary to screen or filter the water before reuse to prevent the plugging of spray nozzles.

The results of NCA studies on product washers emphasize the importance of the final spray wash. It is here that the final cleanliness of the product is established. Fluming and soaking are only a preparation for the final wash. The use of proportionately large volumes of water in tanks or flumes does not lessen the need for a vigorous spray wash.

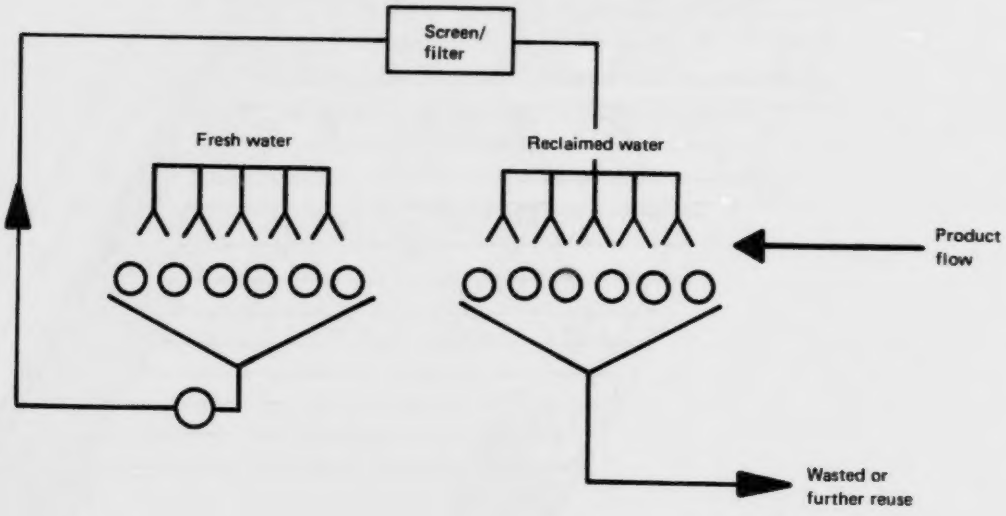


Figure IV-2. Reuse of final rinse water.

Flood Washers

Flood-type washers include dump tanks, immersion tanks, flumes, and flotation washers. These are especially suited for washing leaf vegetables, easily bruised fruits, small particles such as peas and dry beans, and soil-encrusted, mechanically harvested tomatoes. Cleansing is achieved by agitation of the product in water. This action is normally created by recirculating water within the unit. Sand, stones, and other settleable materials are removed periodically through bottom drains or continuously by constant water flow or by mechanical means, depending upon equipment design. In flotation washers, the leaves, stems, and other floatable materials are either skimmed from the water surface or discharged from the unit by a constant overflow.

In all flood washers, soils and other suspended matter are flushed from the unit by the constant addition of clean water. Product cleansing dictates that the rate of clean water addition be sufficient to prevent build-up of contaminants within the system. Water conservation and waste reduction dictate that the rate be carefully adjusted to prevent excessive use of clean water.

Washing efficiencies are greatly enhanced when sprays are used to rinse the raw product as it is conveyed out of a flood-type washer. An arrangement similar to that depicted in figure IV-1 is recommended. Effluent from the rinse sprays may be used in the flood washer to further the use of water.

Reel Washers

Reel washers are revolving cylinders of perforated metal, screening, or metal rods. Such washers are suited for cleaning root vegetables, as well as a variety of fruits and other vegetables. Generally, reel washers are tailored to handle specific products. Cleansing action is facilitated by the raw product units rubbing against each other as they tumble through the reel. A row of spray nozzles placed within the cylinder provides water to lubricate the raw product and to wash away soil and other extraneous debris.

Since the cleansing efficiency of reel washers is dependent upon the use of water, proper selection of spray nozzles is important. High pressure nozzles, either with fan-shaped or solid cone patterns, are recommended. These nozzles are most effective and use less water than flood-type nozzles. To maximize cleansing, attention must be given to the height and spacing of the nozzles within the reel. Product feed rates should be constant; overloading must be avoided.

Brush Washers

Brush washers are suitable for scrubbing root vegetables, especially if the vegetables have been previously soaked. The bristles effectively remove mud from the product surface. Asparagus is also cleaned with this equipment.[8] The brushes must be cleaned continuously with water sprays to prevent recontamination of the product. Minimum water usage requires selection of suitable spray nozzles. High pressure, low volume nozzles are recommended. These should be positioned over the brushes to aid in cleaning the raw product and to cleanse the bristles of mud and other debris.

Combination of Washers

Most commodities will require washing by a combination of two or more methods, such as soaking and flood washing, or soaking and reel or brush washing. Washing or rinsing operations may also be required at several intermediate points in the processing line, such as after peeling or cutting. For all washing and rinsing operations, cleaning efficiencies must not be equated to the quantity of water applied, but rather to the methods in which water is used. In every case a spray rinse will greatly enhance product cleanliness. Careful consideration and proper installation of spray nozzles, as previously discussed, will contribute significantly toward maximizing washing efficiencies while minimizing water consumption.

WASH WATER TEMPERATURE

Washing efficiencies are greatly enhanced when warm water (up to 140°F) is used. However, warm water may detrimentally affect the quality of some raw products. Furthermore, warm temperatures (above 80°F) favor the reproduction of food spoilage organisms.

Cold water is recommended for use in immersion washers (dump tanks, soaking tanks, flumes and flood washers). When bacteriological contamination is of concern in such systems, chlorination may be employed. Only that rate of clean water addition which will maintain a sanitary condition within the system will thus be required.

Warm water may be used to wash raw products if appropriate precautions are observed.

- Since the organic matter contained in the wash water will provide a good medium for bacterial growth, the wash water should be discharged as wastewater after use.
- Chlorination becomes less effective with higher temperatures. When warm water is used in immersion washers, dilution by a high rate of clean water addition must be provided to control microbial populations.

USE OF DETERGENTS

Detergents aid in the removal of soil and other debris from surfaces by increasing the wetability of the contaminants. The effectiveness of detergents is generally increased by using warm water. Detergent baths are effective for washing such products as root vegetables, asparagus, and mechanically harvested tomatoes. The quantity of water required to rinse presoaked commodities will be substantially less when detergents are used in the soaking tanks.

Detergent formulations are widely varied with many being manufactured for specific applications. Only those detergents which have been approved by the Federal Food and Drug Administration for use in food processing operations must be used. Adequate rinsing must follow the application of detergents to assure that no residue is carried into the filled product containers.

POTENTIAL USES OF WATER

Reclaimed water can be used in one of two ways. It can either be reused within the system from which it was recovered (i.e., recirculated) or it can be used in some other operation. Its suitability for use in any operation is dictated by the quality of water required in that operation. Water quality requirements are less stringent for intermediate and preliminary steps with the final operations requiring water of high quality. Water used to convey waste materials can virtually be of any quality aesthetically acceptable. A check list indicating some potential uses of water from various unit operations is provided in table IV-3.

Several methods whereby water may be recovered and reused are described in detail in this chapter. Since water reuse offers the most practical means to significantly reduce hydraulic waste loads, implementation of suitable reuse systems is strongly recommended.

Table IV-3.—*Water-economy check list*[9]

Operation or equipment	May recovered water be used?	May water from this equipment be reused elsewhere in plant?	Source of water for reuse in equipment
1. Acid dip for fruit	Yes	No	Can coolers
2. Washing of product			
A. First wash followed by 2nd wash	Yes	Yes[a]	Can coolers
B. Final wash of product	No	Yes[a]	
3. Flumes			
A. Fluming of unwashed or unprepared product (peas, pumpkin, etc.)	Yes	Yes[a]	Can coolers
B. Fluming partially prepared product	Yes	Yes[a]	
C. Fluming fully prepared product	No	Yes	
D. Fluming of wastes	Yes	No	Any waste water
4. Lye peeling	Yes	No	Can coolers
5. Product-holding vats; product covered with water or brine	No	No	
6. Blanchers — all types			
A. Original filling water	No	No	
B. Replacement or make-up water	No	No	
7. Salt brine quality graders followed by a fresh water wash	Yes	Only in this equipment	
8. Washing pans, trays, etc.			
A. Tank washers-original water	No	No	
B. Spray or make-up water	No	No	
9. Lubrication of product in machines such as pear peelers, fruit size graders, etc.	No	Yes[a]	Can coolers
10. Vacuum concentrators	Yes	In this equipment after cooling and chlorination	
11. Washing empty cans	No	No	
12. Washing cans after closing	Yes	Yes[a]	Can coolers
13. Brine and syrup	No		
14. Processing jars under water	Yes	Food processing	Can coolers & processing waters
15. Can coolers		Water from these coolers may be reused satisfactorily for cooling cans after circulating over cooling towers, if careful attention is paid to proper control of replacement water, and to keeping down bacterial count by chlorination and frequent cleaning.	
A. Cooling canals			
1. Original water	No		
2. Make-up water	Yes		
B. Continuous cookers where cans are partially immersed in water			
1. Original water	No		
2. Make-up water	Yes		

Table IV-3.—*Water-economy check list*[9] *(continued)*

Operation or equipment	May recovered water be used?	May water from this equipment be reused elsewhere in plant?	Source of water for reuse in equipment
15. Can coolers (continued)			
C. Spray coolers with cans not immersed in water	Yes	This water may be reused in other places as indicated.	
D. Batch cooling in retorts	Yes		
16. Cleanup purposes			
A. Preliminary wash	Yes	Yes[a]	Can coolers
B. Final wash	No	No	
17. Box washers	Yes	No	Can coolers

[a] A certain amount of water may be reused for make-up water and in preceding operations if the counterflow principle is used with the recommended precautions.

WATER RECIRCULATION SYSTEMS

The use of water in some systems may be extended by recirculating the water in a cyclic, or closed-loop, fashion. Once such systems are filled, water consumption will be limited to the volume required to maintain a proper level or acceptable water quality within the units. To enable reuse of water in this manner, treatment procedures may be required. Generally, this disadvantage will be more than offset by the benefits accrued through reduced water usage and wastewater generation.

There are three principal operations which readily lend themselves to water recirculation. These are (1) can cooling or freezer compressor cooling waters, (2) raw product fluming water, and (3) product concentrator or evaporator water. Although only these are discussed in this chapter, the principles and procedures which are described may be applied to other special situations.

CAN COOLING WATER

Water is used to cool containers after thermal processing. To prevent the possibility of spoilage due to recontamination, chlorination of can cooling water is recommended. Regardless of the type of cooling equipment used, the water must be continuously replaced to maintain the proper temperature to accomplish the designated task. A constant overflow of relatively clean, warm water results. If the temperature of this effluent stream is reduced, the water may be reused to cool additional containers.

Cooling towers are being successfully and advantageously used to reduce the temperature of cooling waters (see figure IV-3). When cooling towers are used, the following precautions should be observed:

1. Chlorination: Sufficient chlorine should be added to the water after it has passed over the tower to maintain a residual of approximately 0.5 ppm at the end of the cycle. Since this amount is not adequate to prevent all growth of microorganisms, the chlorine residual should be increased to 4-5 ppm for a short time about every two weeks.

2. Screening: It is advisable to screen all water before passage over the tower to remove any large pieces of foreign matter.

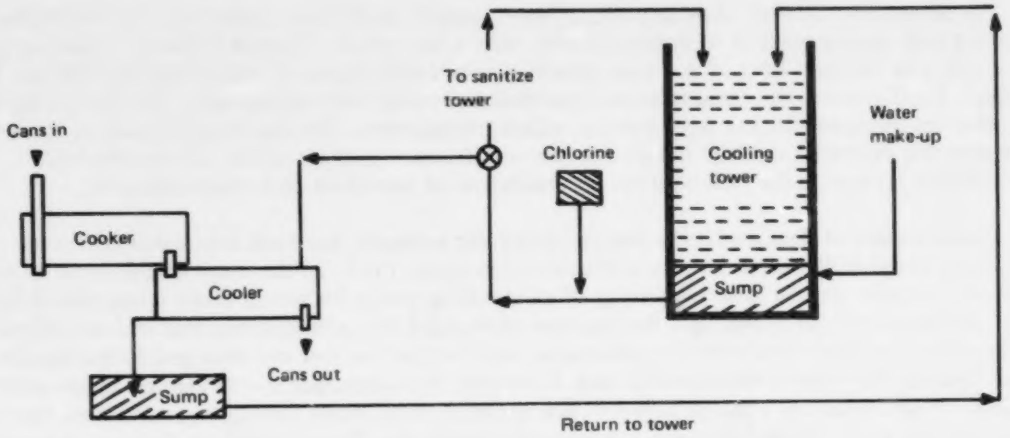


Figure IV-3. Chlorination of can cooling water recycled over a cooling tower.

3. Can washing: All cans must be thoroughly washed preferably with hot water after closing and before entering the cooker, to prevent syrup, oil, or other adhering food material from contaminating the cooling water.

4. Replacement water: Sufficient replacement water should be added to prevent concentration of minerals (salts) to the point where spotting of containers becomes a problem.

Can cooling water may also be recovered and used in other operations, thereby reducing the volume of water consumed by the total plant operation. Can cooling water may be used directly in washers or cooled and used for product rinsing or as make-up water in flumes.

COMPRESSOR COOLING WATER

Although the volume of water used to cool freezer compressors may be relatively minor when compared to other effluent streams, the quantity annually consumed for this purpose is generally significant. The quantity of water required to cool compressors can be drastically reduced by collecting, cooling and recycling the warm effluent. Cooling towers can be advantageously used to lower the temperature of the water.

Since compressor cooling water does not contain organic contaminants, only minimal chlorination of the water will be required prior to passage over a cooling tower. The sole purpose of chlorination is to control algal growth in the tower. The water replacement rate may generally be limited to that which is required to maintain the necessary water level within the system. In situations where extremely hard water results in rapid and problematic concentration of salts, chelating agents may be used to minimize the volume of fresh water otherwise required for dilution.

PRODUCT FLUMING WATER

The state of the raw product being conveyed largely determines the quality of water which is required in a flume. Flumes for conveying and washing raw products (such as beets, tomatoes, and other unprepared fruits and vegetables) do not require fresh water. On the other hand, partially prepared products (such as blanched vegetables and cut fruits) should be flumed in water of good sanitary quality. In all cases water may be recirculated in flumes provided that clean water, with or without chlorination, is added at a rate sufficient to maintain satisfactory conditions within each system.

An undesirable feature of recirculating flume water is the inherent tendency for developing relatively high concentrations of organic matter within the system. Each successive contact of the water with raw product adds to the total dissolved solids and organic content until equilibrium is reached. Furthermore, the temperature of recirculated water tends to increase, thereby creating a favorable environment for the reproduction of microorganisms. The resulting increase in spore loads aggravates the potential spoilage hazard for low-acid foods. Another matter of concern with recirculation systems is the potential for accumulation of pesticides and other chemicals.

Conservation of flume water in pea canneries, for example, has been accomplished by recirculating water within unit systems as illustrated in figure IV-4. In the usual arrangement of such a system, the peas are fed into the hopper of an elevating pump for which water is supplied from a tank. At the end of the pump line, the peas are discharged into a dewatering reel and are delivered to the next operation. The water is collected in a pan under the reel and returned to the supply tank. Usually the water is returned through the screen of a scavenger reel to remove larger solid particles. Fresh make-up water is added to the system continuously through an adjustable valve and intermittantly upon demand through a float-controlled valve. The sanitary condition of the water is largely determined by the amount of fresh water added to the system.

Buildup of particulate matter in a recirculated system can be minimized by incorporating a trash screen in the return line, as depicted in figure IV-4. Carryover of bacteria from the system can be minimized by rinsing the product with fresh or clean water. The rinse water can then be added to the system for make-up and/or dilution.

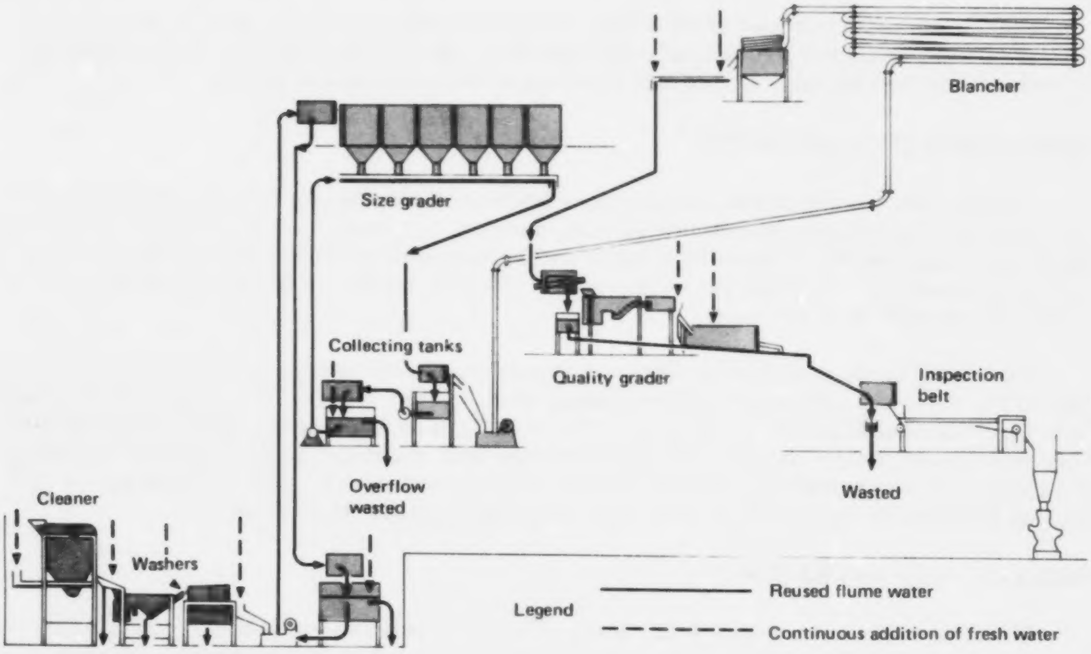


Figure IV-4. Diagram of water flow in a flume system (with recirculated water in two operations and reused water from a third operation to flume peas to the inspection belts).

Controlling the concentration of organic matter and bacterial numbers in recirculating flumes by dilution would require the addition of clean water at a variable but high replacement rate. Although this practice will greatly reduce wastewater volumes compared to single-use fluming systems, the resultant waste load will still be considerable. Waste generation and bacterial numbers can be more effectively controlled by counterflow reuse and chlorination of water. When fluming peaches, apples and other high-acid products, bacterial numbers can be controlled with minimal dilution by controlling the pH of flume waters to 4.0 or less.

EVAPORATOR WATER

One type of evaporator widely used to concentrate tomato and fruit juices, fish solubles, and other food products employs a barometric leg to create a vacuum in the unit in order to condense vapors emanating therefrom (figure IV-5). Cold water injected into the barometric leg condenses water vapor and volatile organics while absorbing the heat of vaporization. Since the exit temperature of the water is one of the parameters which determines the efficiency of operation, cold water injection rates are closely controlled.

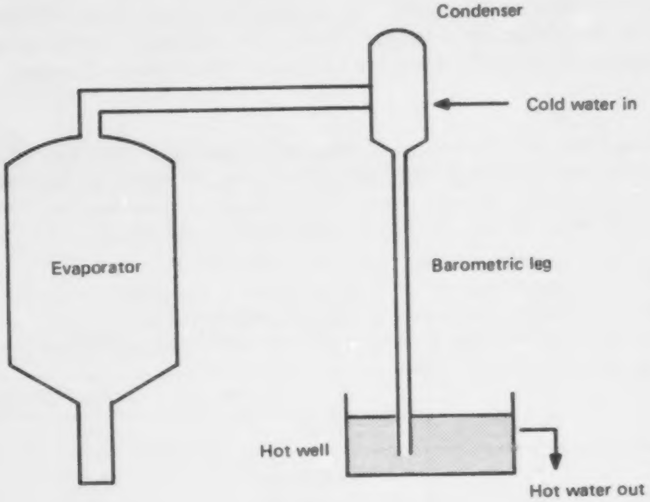


Figure IV-5. Barometric condenser water.

A multi-effect evaporator can consume a large quantity of water (in excess of 1,000 gpm). Because the effluent is warm (generally around 120°F) and may contain traces of organic matter, the water is often wasted. However, this water is suitable for reuse. Since the effluent volume is large, cooling and recycling offer the greatest potential for reducing the wastewater volume. Cooling towers are being advantageously used for this purpose. Although the thermodynamics will differ, the application is similar to the recovery of can cooling and freezer compressor waters. Fresh water additions may be required to control concentrations of minerals and organic matter. The resultant overflow from the system can be readily used elsewhere in the plant.

THE COUNTERFLOW WATER REUSE SYSTEM

Preparatory operations in food processing are designed to assure the delivery of clean, wholesome products to the final packaging operation. Water is used at various stages to separate and remove undesirable materials, such as leaves, soil, immature and overripe products, and bacterial contaminants. To assure product cleanliness, water used in final washing and rinsing operations must be of highest sanitary quality, whereas water used in preceding operations need not necessarily meet such stringent sanitary requirements. This premise is the basis upon which counterflow water reuse systems have been developed.

Counterflow water systems are designed to minimize the quantity of water required to effectively prepare clean foods, thereby minimizing waste loads associated with food processing. Basically, most of the fresh water is used in the final operation, collected and reused in a previous operation, and recollected and reused in this manner one or more additional times. Since the water always passes counter to the flow of the product, the product comes into contact with subsequently cleaner water and is finally washed or rinsed with fresh water. Although the following discussion concerns counterflow reuse in pea processing, the principles may be applied to the processing of any commodity.

The sanitary condition of water is normally evaluated by measuring the bacterial population in the water. The sanitary condition of raw product is directly influenced by the bacteria count of the water with which it comes in contact. The condition of pea fluming waters was monitored during a study in which recirculation was compared to counterflow reuse with different chlorination practices.[9] The results are summarized in table IV-4. The comparative bacteria counts clearly indicate the effectiveness of product cleansing by counterflow reuse of water.

Table IV-4.—*Comparison of total numbers of bacteria in flume waters reused by recirculation and by counterflow methods, and comparison of the effect of varying the extent of chlorination in these waters*[9]

Method of water reuse and extent of chlorination in each plant:

Plant A – Water recirculated; in-plant chlorination only.
Plant B – Counterflow reuse; no chlorination at any point.
Plant C – Counterflow reuse; in-plant chlorination only.
Plant D – Counterflow reuse; in-plant chlorination plus rechlorination.

Use of water sampled	Plant	Bacteria count[a] per ml of water		
		High	Low	Average
Water used to flume peas from quality graders to inspection belts	A	23,000,000	27,000	4,729,000
	B	350,000	13,000	65,200
	C	14,500	2,300	6,300
	D	3,500	400	1,300
Water used to pump or flume peas from blanchers to quality graders	A	1,800,000,000	590,000	365,590,000
	B	1,900,000	77,000	611,000
	C	220,000	14,000	58,760
	D	21,000	700	6,250
Water used to flume peas from size graders to blanchers	A	78,000,000	98,500	15,752,000
	B	2,900,000	50,000	837,200
	C	190,000	10,000	40,140
	D	130,000	2,300	22,470
Water used to flume peas from washers to size graders	A	52,400,000	91,000	13,752,300
	B	11,000,000	350,000	1,780,000
	C	130,000	14,000	47,180
	D	140,000	3,500	31,610

[a] Bacteria counts represent the numbers of colonies growing on glucose-tryptone agar plates inoculated with unheated flume water and incubated for 48 hours at 86° F.

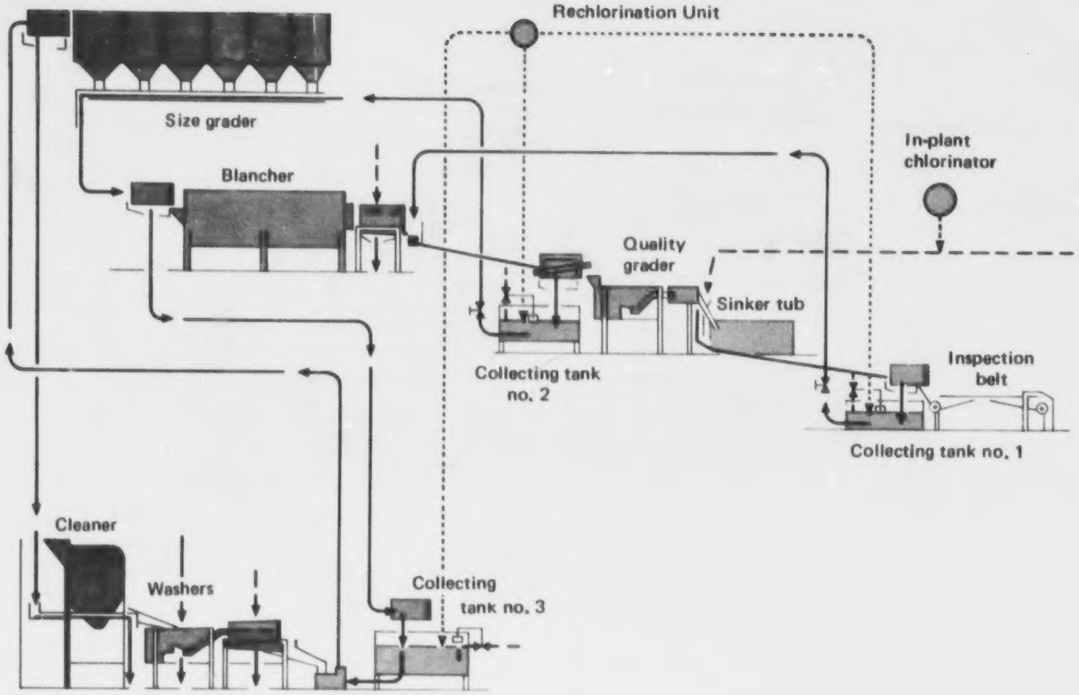

Rechlorination Unit
Size grader
In-plant chlorinator
Blancher
Quality grader
Sinker tub
Inspection belt
Collecting tank no. 2
Collecting tank no. 1
Cleaner
Washers
Collecting tank no. 3

Figure IV-6. General plan for counterflow reuse of flume water in a pea cannery.

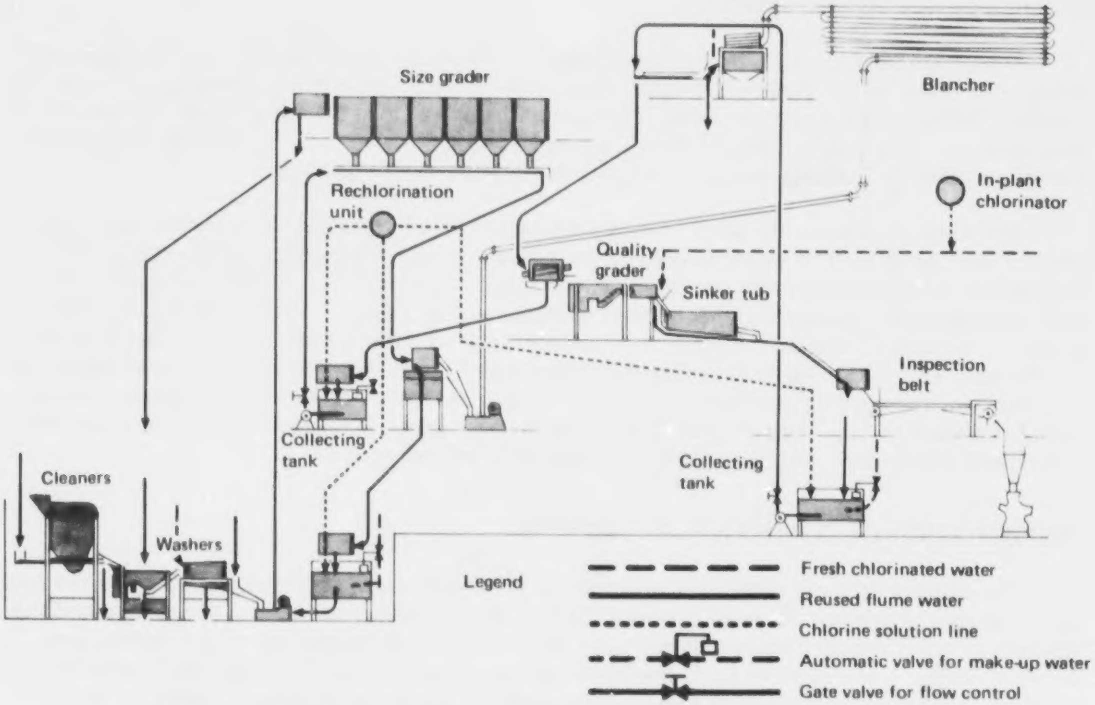

Size grader
Blancher
Rechlorination unit
In-plant chlorinator
Quality grader
Sinker tub
Inspection belt
Collecting tank
Collecting tank
Cleaners
Washers
Legend
Fresh chlorinated water
Reused flume water
Chlorine solution line
Automatic valve for make-up water
Gate valve for flow control

Figure IV-7. Plan of counterflow reuse system designed to eliminate undesirable features of flume system shown in figure IV-4.

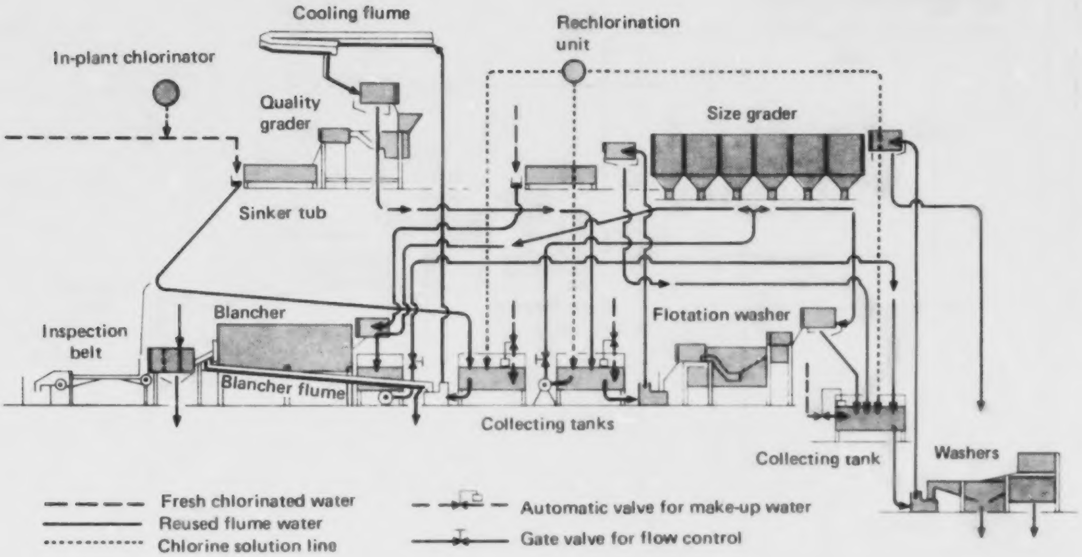

Cooling flume
Rechlorination unit
In-plant chlorinator
Quality grader
Size grader
Sinker tub
Blancher
Inspection belt
Flotation washer
Blancher flume
Collecting tanks
Collecting tank
Washers
Fresh chlorinated water
Reused flume water
Chlorine solution line
Automatic valve for make-up water
Gate valve for flow control

Figure IV-8. Plan for counterflow reuse of water in a pea cannery where line arrangements require extensive fluming operations

A FOUR-STAGE REUSE SYSTEM

A general plan for counterflow reuse of flume water in a pea cannery is shown in figure IV-6. In this plan most of the fresh water enters the system as flume water for conveying peas from the quality graders to the inspection belts. This is the final washing of the peas before they are filled into the cans. The water separated from the peas at the inspection belts is collected and used for the second time in fluming peas from the blanchers to the quality graders.

The water is used for the third time in fluming peas from the size graders to the blanchers, and for the fourth time to pump peas from the washers to the size graders. At the size graders, the water is separated from the peas by means of a reel. From this point it may be used in the first washing of the peas or may be diverted to flumes which remove wastes from beneath the cleaners. Figures IV-7 and IV-8 show counterflow reuse schemes for different arrangements of equipment. (Figure IV-7 may be compared with figure IV-4 to illustrate the differences between recirculation and counterflow reuse of water.) In each case rechlorination of the water is recommended after each use. As indicated by the results summarized in table IV-4, rechlorination will effectively reduce and control bacterial populations in reused water.

INSTALLATION OF COUNTERFLOW SYSTEMS

The amount of water which can be saved by a counterflow reuse system will depend primarily on the degree of balance obtained between the rate of fresh water addition to the system and the amount of water required to adequately carry out the different operations. If the system is to be water-saving, there must be no appreciable wastage of water other than that which may be required to maintain aesthetically acceptable conditions within the system. In order to obtain maximum benefits with minimum supervision, the system should include collection tanks, screens, and appropriate water valves.

Collection Tanks

After each use, the water should be collected in a tank from which it may be delivered by pump or gravity to the next operation. Ordinarily the water used in the same fluming operation on all of the canning lines should be brought into one collecting tank. For example, in figure IV-6, all of the water used to flume peas from quality graders to inspection belts would be collected in Tank No. 1. It is important that water from a later stage in the reuse system not be added to this tank. The tank should have sufficient capacity to contain, without overflowing, all of the water which would be delivered to it when all lines are in operation.

Screens for Reused Water

To prevent the accumulation of particulate matter in reused water, fine mesh screens should be provided at each collection tank. Removal of particulates will extend the reusability of reclaimed water. Dry systems to collect and transport the accumulated solids should be provided.

Automatic Valves for Fresh Water Make-Up

Fresh water lines, equipped with float-controlled valves, should be provided at each collecting tank. These valves will eliminate the possibility of the tank becoming empty, thereby protecting the pump and assuring that an adequate supply of water is available for the subsequent operation.

Control of Flow Rates

Minimization of water usage by the counterflow reuse method depends entirely upon maintaining balances between the several component subsystems. Water withdrawn from any collection tank must not exceed that volume which is required by the next operation. In addition, the withdrawal rate from any collection tank should not greatly exceed the previously used water supply rate.

Careful planning is a definite prerequisite to successful implementation of counterflow reuse systems. Control of such systems will be facilitated by the use of variable speed pumps for adjusting all flow rates. Alternately, gate valves, installed in the lines immediately after the pumps, can be used to regulate the water withdrawal rate from each tank to correspond to the water requirement in the next operation. In either case, periodic adjustments may be required to assure maintenance of appropriate balances and maximum efficiencies.

Cooling and Washing Requirements

In the usual arrangement of the counterflow system for peas, the second use of water is for fluming or pumping peas from blanchers to quality graders. This fluming operation requires more careful attention than the other. The peas are discharged from blanchers at an average temperature of 200°F and are covered with varying amounts of foam and blanch water high in organic solids. In some cases the blanchers may be contaminated with thermophilic flat-sour bacteria, the spores of which will be on the peas. If these peas are discharged into the flume while still hot, the sanitation of the third and fourth stages of the reuse system may be greatly impaired. Warm water will favor rapid microbial growth which can cause excessive slime growth on equipment.

Of more serious consequence, however, is the increased potential for flat-sour spoilage in canned peas. Studies have shown that blanched peas not previously cooled before entering the flumes to the quality grader may reach the grader with a temperature still above 100°F. Elevated temperature in water which has a high concentration of organic matter will be favorable to the growth of thermophilic bacteria in the flumes. Furthermore, failure to adequately wash blanched peas can result in an accumulation of thermophilic spores in the quality grader brine.

Impairment of water quality due to factors attributable to blanchers can be prevented or greatly minimized by cooling and washing blanched vegetables in a separate operation. Equipment which can be used for this purpose (listed in the order of preference) include air coolers, vibrating screens with overhead sprays, reel washers and hydrocooling flumes. Sprays used with vibrating screens or reel washers should be supplied with cold, chlorinated water. Since the volume of water used by these units is relatively small, the wash water can be wasted without contributing significantly to the total plant effluent. Discharging of the wash water will enable more extensive reuse of the large volume of water in the counterflow system by minimizing heat input and by preventing excessive amounts of organic matter and bacteria from accumulating within the reuse system.

Water Saved

Under average conditions, it has been estimated that the installation of a counterflow reuse system will reduce the total water consumption by approximately 50 per cent of the volume which would otherwise be used if fresh water is used in all operations. However, the amount of water which can be saved by installing a counterflow system depends upon the unit operations within each plant. Estimations of potential water savings and waste load reductions can be made by surveying the processing plant and monitoring each wastewater flow.

SPECIAL WATER REUSE SYSTEMS

Variations in plant layouts, processing operations, types of equipment, and varying urgencies to conserve water and/or reduce waste loads, not to exclude variable waste characteristics, are but a few of the many reasons that detailed discussion of specific water reuse systems are of limited value. Instead, coverage of general principles which can be adapted to a variety of situations have been attempted in the preceding sections. However, some unique situations offer potentially widespread applications as solutions to common problems. For this reason, the following special systems are described.

"TRIPLE DUTY" WATER REUSE SYSTEM

An advanced type of water reuse system in a specialty foods plant has recently been reported.[10] This system has been designed not only to conserve water, but also to conserve heat energy. As depicted in figure IV-9, the system consists of two parallel closed loops and a third open-ended leg. The main feature of the closed loop circuits is the sterilization tank. Make-up water added to the system at this tank is recovered air compressor cooling water and condensate from cereal drum dryers and building heaters. The water is treated with ozone, pumped through a vertical cartridge-type filter heated to 190°F in a shell-and-tube heat-exchanger, and supplied to the two closed loop systems.

Water in the first loop is used to wash empty jars. The wash water is collected in a sump, pumped through a filter and returned to the sterilizing tank. In the second loop, the water is used to fill retorts. Effluent from the retorts is collected in two separate sumps. Water with a temperature above 150°F is collected in one sump, while water below 150°F is collected in the other. The hot water is filtered and returned to the sterilization tank, thereby completing the second circuit. By segregating and recycling only the hot water, less energy is required to reheat water from the sterilization tank, thus resulting in a conservation of heat and fuel. Water below 150°F from the retorts is used in the final leg of the system. This water is used for flushing gutters and cleaning floors in processing areas and is discharged thereafter to waste.

SEDIMENTATION – CARBON FILTRATION WATER RECOVERY SYSTEM

A treatment and recovery system was designed to remove suspended and dissolved solids and to reduce the bacterial load from green bean processing wastewater.[11] A simplified diagram of the system is shown in figure IV-10. The special feature of the water recovery operation is the sedimentation and carbon filtration treatment system which clarifies the used water sufficiently for recycling through the canning operations.

The Water System

The water reservoir may be considered the starting point of the cycle. It is divided into two compartments, one containing 40,000 gallons of fresh water and the other a 20,000-gallon mixture of recovered water and fresh water. In this way, a supply of fresh water is readily available in the event of system malfunction. Air is bubbled through the recovered water compartment to increase dissolved oxygen. Chlorine in the form of hypochlorite is added periodically to the reservoir.

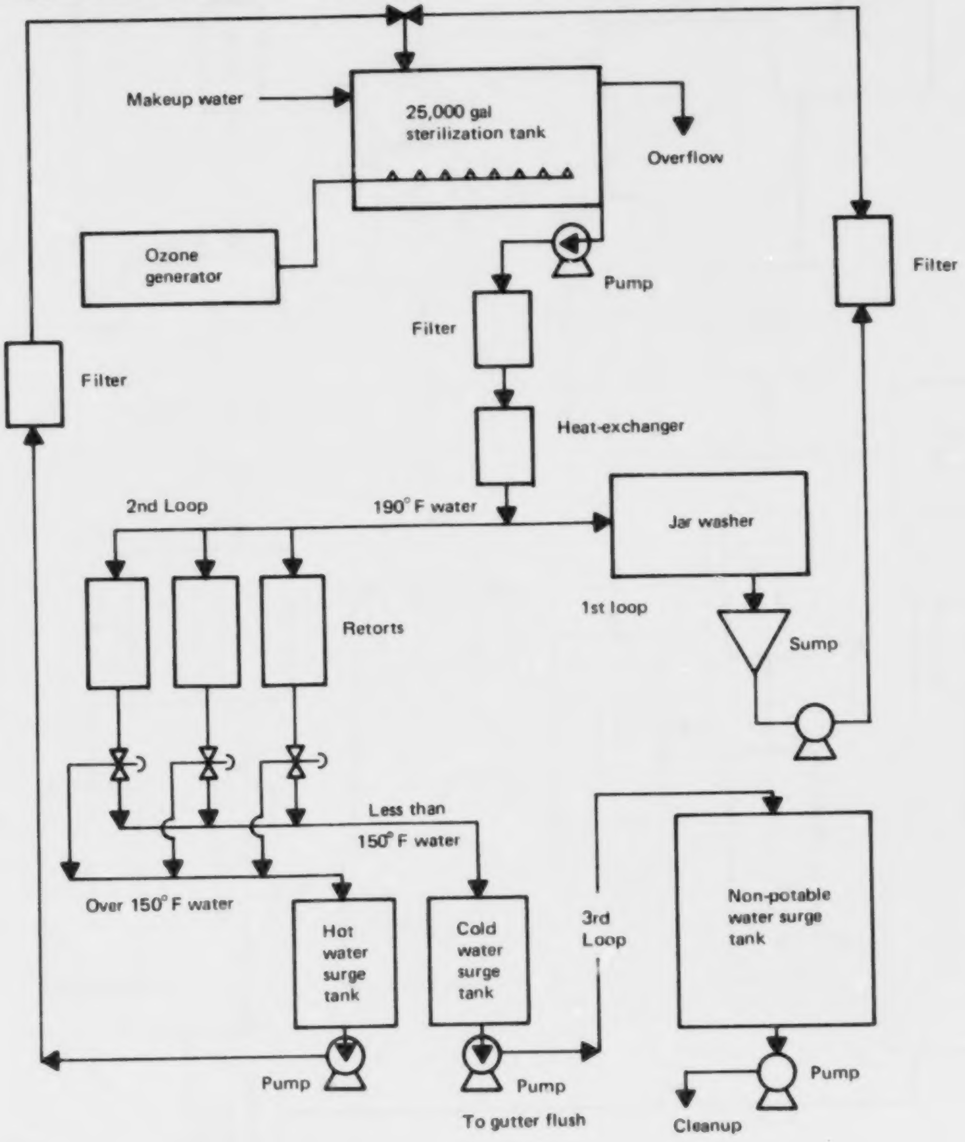

Makeup water
25,000 gal sterilization tank
Overflow
Ozone generator
Pump
Filter
Filter
Filter
Heat-exchanger
2nd Loop
190° F water
Jar washer
1st loop
Sump
Retorts
Less than 150° F water
Over 150° F water
Hot water surge tank
Cold water surge tank
3rd Loop
Non-potable water surge tank
Pump
Pump
To gutter flush
Pump
Cleanup

Figure IV-9. Triple duty water reuse system.

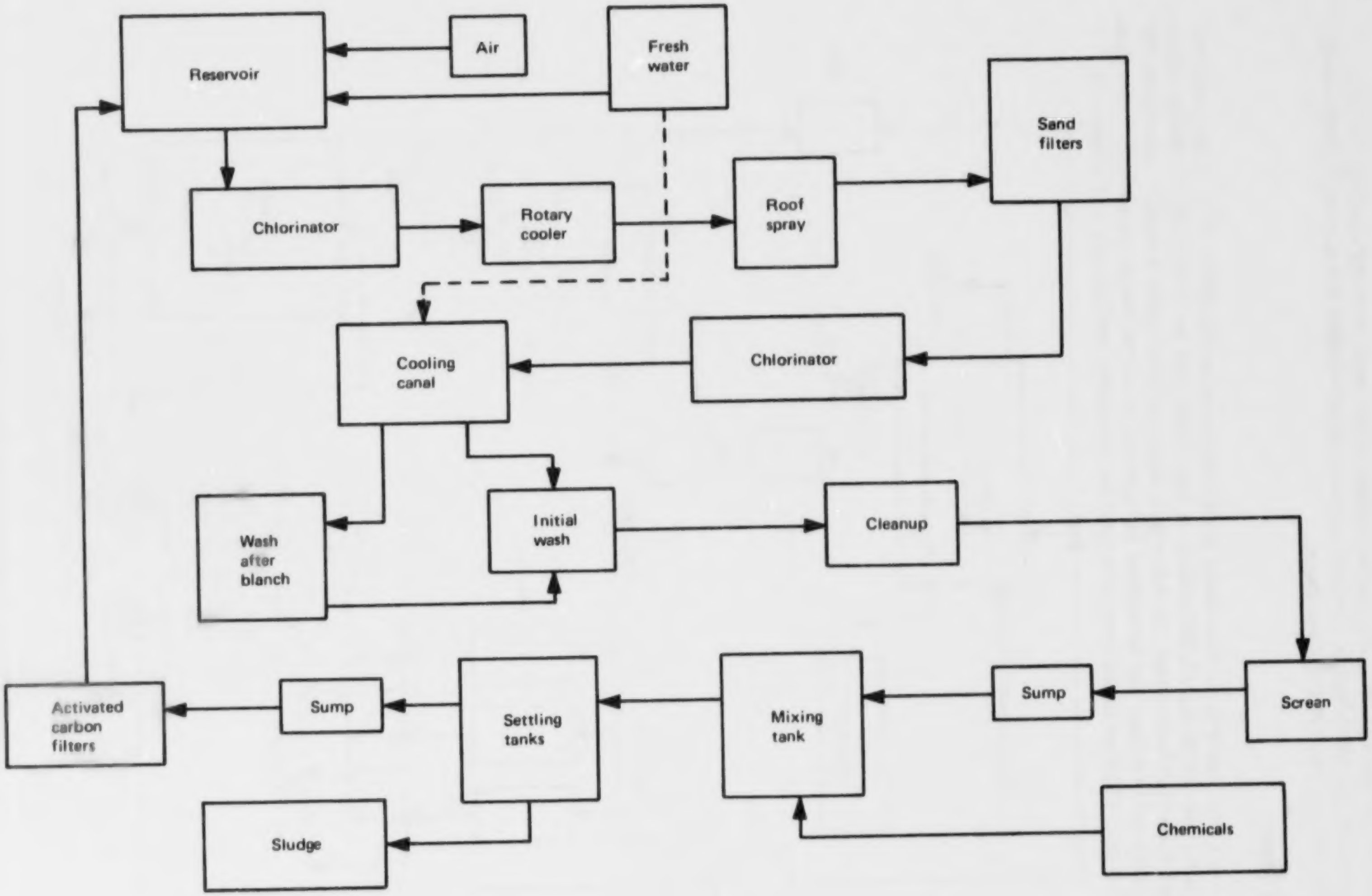

Reservoir
Air
Fresh water
Sand filters
Chlorinator
Rotary cooler
Roof spray
Cooling canal
Chlorinator
Wash after blanch
Initial wash
Cleanup
Activated carbon filters
Sump
Settling tanks
Mixing tank
Sump
Screen
Sludge
Chemicals

Figure IV-10. Diagram of charcoal filtration water recovery system.

Water is pumped from the recovered water compartment to the first chlorinator, where sufficient chlorine is added to give 1 ppm free residual. From the chlorinator, some water is sent to the rotary can cooler and the remainder is sent to the can cooling canal. The water from the rotary cooler is sprayed cooled, filtered through sand, chlorinated, and added to the can cooling canal. The water overflow from the cooling canal is used in three ways: for product washing after blanching, for initial product washing, and in the plant drains to carry out solid wastes. Water used for both product washing operations is combined with the plant drain water and channeled to the treatment area for screening. Particles larger than 1/2 inch are removed by passing the wastewater stream through a mesh belt conveyor. Waste particles smaller than 1/2 inch are removed by a 48-mesh, 60° tangential screen. The screened wastewater is divided into three portions. One portion is pumped directly into the plant to flush the floor drains. Another portion is piped into the water recovery system. The remainder of the liquid waste is discharged.

The Treatment System

The recovery system consists of coagulation, sedimentation, and filtration treatments. When operating properly, the system is designed to remove all traces of suspended matter, including colloidal particles. Under ideal conditions, the filter effluent will be almost free of bacteria. Caustic soda, aluminum sulfate, and a polyelectrolyte (flocculent aid) are added to the screened wastewater in a flash mixing tank. After a 3-minute detention period, the mixture is delivered to two flocculating tanks, each of which provides a 10-minute detention. Air is injected into the tanks to provide agitation and facilitate flocculation. Flocculated solids are removed as a sludge from the settling tank and are discharged to a lagoon. The clarified water is filtered at the rate of 50 gpm through a 5-foot bed of activated carbon and is returned to the water reservoir.

Treatment Results

The reduction in fresh water consumption achieved with the reuse treatment system is shown in table IV-5. The recovery system resulted in an 18.4% reduction in fresh water consumption by the canning plant during the first year and a 25.4% reduction during the second year. The hydraulic loading on the waste disposal system was thus reduced by a corresponding proportion.

It should be emphasized that the data are derived from wastewater resulting from a single product operation, green bean canning. This water recovery system works well for this plant and for this particular product. Water from multi-product operations may be more difficult to treat; each system should be considered individually. However, the results indicate that wastewater reclamation and reuse is feasible without undue risk of canned product spoilage.

pH CONTROL OF RECIRCULATED WATER

The use of hydraulic conveying systems by food processors is extensive in view of the advantages which such systems offer. These advantages are as follows: water is a convenient and efficient transport medium; hydraulic systems are generally more compact than dry conveyors; little attention is required for operation of hydraulic systems; and maintenance of product appearance is enhanced by the gentle handling imparted by water. To maintain acceptable aesthetic and sanitary conditions within hydraulic conveying systems, a large volume of water is generally added continuously, thereby resulting in a continuous overflow from the system. By dilution in this manner, food particles and product juices which are washed or leached from the conveyed commodity are maintained at low concentrations within the system; microbial populations are likewise minimized. Where hydraulic conveying systems are used, the organic matter which is continuously discharged from each system is a major source of the total organic load associated with the processing operations. The water discharged from each system is a major contributor to the total hydraulic load of the plant effluent. Measures to reduce the waste loads from hydraulic conveying systems must include consideration of the sanitary condition of the water within the systems.

Table IV-5.—*Effect of water recovery system on water usage in canning green beans*[10]

Date	Gals/case fresh water only	Gals/case using recovered water	Percent decrease
8-7-67	22.9	16.4	28.4
8-9-67	26.5	18.2	31.3
8-11-67	32.9	22.2	32.5
8-29-67	27.2	20.3	25.4
8-31-67	24.3	19.3	20.6
Average	26.8	19.3	28.0
1967 Season[a]	25.5	20.8	18.4
1968 Season[a]	20.8	15.8	25.4

[a] For periods when recovery system was used.

It is well established that the pH of water affects the growth rate of microorganisms. The optimum pH for most bacteria is in the neutral range (pH 6.5 to 7.5). As the pH of the medium is made more acidic or more basic, microbial growth rates decline. Under very acidic or very basic conditions, bacteriostatic effects are evidenced. The growth responses observed in a simulated flume system are graphically illustrated in figure IV-11.[12] These results are the basis for the use of pH control to maintain the sanitary condition of recirculated water. This control methodology is especially well suited for systems conveying naturally acid products (such as tree fruits and tomatoes) and may be used for potatoes and other vegetables.

EXPERIMENTAL RESULTS

A demonstration project was conducted to confirm on a commercial scale the findings of the earlier laboratory study.[13] Two identical pumping systems were used for this investigation. In each of these systems, cling peach halves were discharged into tanks and pumped to the filling operation. The peaches were dewatered and delivered to can fillers. The water was then returned to surge tanks for recycling. Fresh water could be added to each system as required. In one system, pH control capabilities were provided, as graphically depicted in figure IV-12. Citric acid, an edible acid which naturally occurs in fruits and tomatoes, was used to acidify and maintain the water at pH 4.0. The parameters monitored for each system included the volume of water consumed, bacterial counts on representative samples, temperature, pH and BOD. The quantity of acid used in the test system was also measured.

The amount of fresh water added to each system and the quantity of BOD generated by each are summarized in table IV-6. In this case, the acidified pumping system used only 25 percent as much fresh water and generated only 70 percent as much BOD as did the unacidified control system.

The quantity of citric acid required to maintain pH 4 within the system will be dictated by the rate of fresh water addition, as well as the pH and buffering capacity of the raw water and commodity being transported. Citric acid consumption in relation to the volume of water added to the system (averaged over several days of operation under the test conditions described) is summarized in table IV-7.

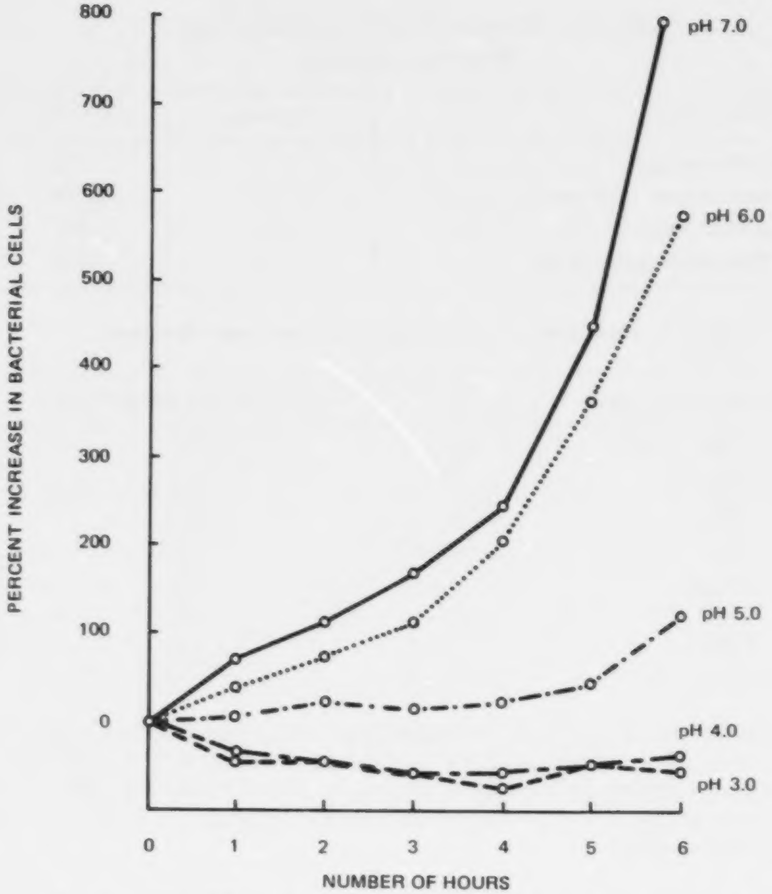


Figure IV-11. Effect of pH control on the growth of bacterial cells.[12]

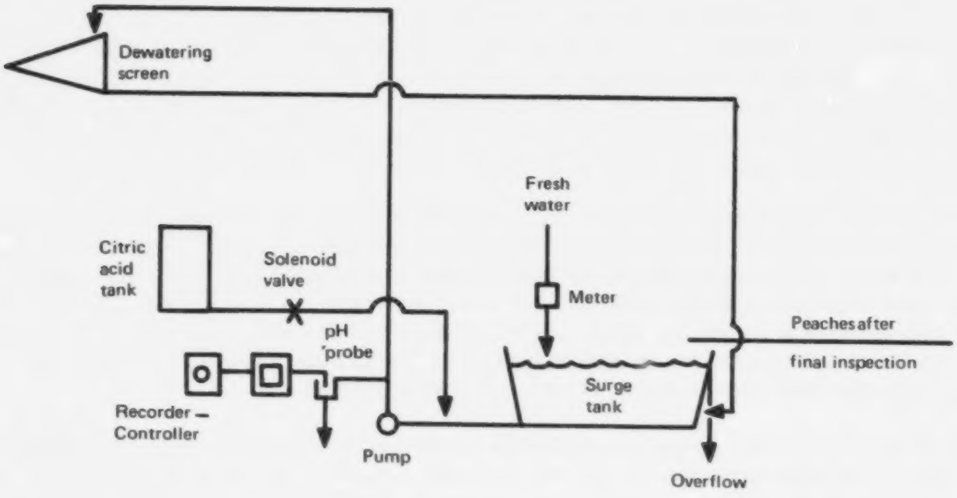

Dewatering screen
Fresh water
Citric acid tank
Solenoid valve
Meter
pH probe
Peaches after
final inspection
Surge tank
Recorder – Controller
Pump
Overflow

Figure IV-12. pH control system.[13]

Table IV-6.—*Characteristics of fruit pumping water (24 hours of operation)*

Measurement	Acidified	Control
Water make-up, gpm	5	20
Total water volume used, gallons	6,720	26,520
Average BOD, ppm	2,034	742
Total BOD discharged, pounds	118	170

Table IV-7.—*Critic acid consumption at various fresh water flow rates*

Flow in gallons per hour	Lbs citric acid added per hour
65	2.1
160	2.3
220	2.4
330	2.8
420	3.1
560	3.2
700	3.6

Results of tests performed on samples collected from the two systems are summarized in table IV-8. The relative bacterial count was obtained by reducing the total plate count to a common denominator. Results are reported for samples taken at 2-hour intervals over a 24-hour period. Almost without exception, the bacterial count in the acidified system was equal to or lower than the count in the control system.

Use of the pH control system resulted in reduced consumption of water required to maintain sanitary conditions in the recirculated water system. The acidified system was operated at the make-up rate equal to 25 percent of the control system. The second principal benefit of using less water is the resultant reduction in the volume of effluent. Using the current water charges in one California community, the reduced intake of fresh water would pay for the citric acid used in controlling the pH of the water. A water savings of 20,000 gallons per day would reduce the water bill by $6.00. Using an average of 2.5 pounds of citric acid per hour at 10 cents per pound, the cost of the acid would be equal to the savings in the smaller volume of water used. There would be a net savings in sewer service charges for the reduction in the volume of effluent and pounds of BOD discharged.

The pH control system was operated continuously for only 24-hour periods. It is very possible that even longer periods of operation could be used and the consumption of fresh water further reduced. This would result in even greater savings in water and citric acid, with fewer pounds of BOD discharged. Had recirulation of the acidified water extended beyond 24 hours, there may have been an even greater increase in the soluble solids content of the recycled water. In this case, the osmotic exchange between product and water would decrease. This would mean less leaching from the product and a further reduction in the BOD load of the recycled system.

Fresh water addition into the system should be controlled by a properly installed float-actuated valve. If continuous addition of water is deemed desirable, the rate of addition should be minimal. In some situations, product fragments and other debris may tend to accumulate within the system. A screening device incorporated into the return water line will facilitate removal of such objectionable materials and extend the usability of the recirculated water.

Table IV-8.—*Comparison of control & test systems*

Time of sampling	Total count x 10^{10}		pH		Temp. °F	
	Test system	Control system	Test system	Control system	Test system	Control system
6 a.m.	0.5	6	4.4	7.6	67	67
8 a.m.	63	138	4.1	7.2	72	70
10 a.m.	72	226	3.9	7.3	75	72
12 noon	39	106	3.8	7.4	72	70
2 p.m.	84	137	3.9	7.4	74	70
4 p.m.	61	111	4.0	7.4	76	72
6 p.m.	97	60	3.9	7.7	76	70
8 p.m.	41	82	3.8	7.4	75	71
10 p.m.	67	80	3.9	7.2	76	72
12 midnight	13	22	3.8	7.5	75	69
2 a.m.	2	59	3.8	7.4	74	69
4 a.m.	17	9	3.8	7.3	75	71

Foaming may be encountered in recycled systems as a result of the accumulation of soluble organic matter. This can be controlled by the addition of an approved anti-foam substance or by the installation of fine mist sprays in the area where the foam accumulates.

Although microbial growth can be effectively controlled in an acidified system, it is important to insure that the system does contain "dead ends" or blind spots which may provide favorable harbors for microorganisms.

B. DISINFECTION

The disinfection of water supplies has been employed for many years as a safeguard against waterborne disease. In recent years industrial water chlorination has become common practice in fruit and vegetable processing plants to improve plant sanitation. With the increasing ecological desirability of conserving water, the economic necessity of reducing the volume of wastewater requiring treatment and disposal, and the added emphasis on plant sanitation, the use of disinfectants has become an even more important factor in the continued assurance of producing wholesome, quality foods.

The cost and effectiveness of various germicides vary widely. Selection of appropriate compounds will require knowledge of the relative advantages and limitations of each. The following sections describe chlorine and chlorine compounds, as well as other germicides, and their application in water reuse systems and waste prevention programs in food processing plants.

CHLORINE AND CHLORINE COMPOUNDS

GASEOUS CHLORINE

Chlorine is prepared commercially by the electrolytic decomposition of sodium or potassium chloride solution. It can be used as a gas or as one of its compounds. Under ordinary atmospheric pressure, chlorine is a greenish-yellow gas about two and one-half times heavier than air. Due to this greater density, it will flow to the lower levels of a room or building. Chlorine is nonflammable and nonexplosive. However, it reacts chemically with many substances and may cause a fire or explosion when in contact with combustible materials. In the presence of moisture, it is very corrosive to common metals. Chlorine is only slightly soluble in water, the maximum solubility being about 1% at 49.2°F. As the temperature increases, the solubility decreases until it is zero at the boiling point of water. Chlorine combines with water below 49.2°F to form crystalline hydrates commonly called chlorine ice.

Gaseous chlorine containers range from 150 pounds to 30 tons, or tank car, capacity. For industrial use where the daily requirements are less than 50 pounds per 24 hours, 150-lb. cylinders are suggested. At plants having greater requirements than this, there is generally an advantage in purchasing chlorine in one-ton cylinders.

HYPOCHLORITES

Calcium and sodium hypochlorites are extensively used for chlorination of industrial waters. Sodium hypochlorites are sold as liquids, while calcium hypochlorites are marketed in the powdered form. They are prepared by treating the respective alkalis with chlorine gas. The degree of chlorination determines the percent of available chlorine. In the case of calcium hypochlorites, a tendency for powders to cake is attributed to impurities in the lime.

CHLORAMINES

Chloramines, formed by the reaction of chlorine with ammonium nitrogen in an aqueous solution, are more stable and much less corrosive than the hypochlorites. Formation of chloramines is a reversible reaction, resulting in the formation of undissociated HOCl in low concentration when chloramine is dissolved in water. The dichloramine is the most effective disinfectant.

Action of chloramines is slower but longer lasting than that of hypochlorites. They are particularly useful in situations where a long contact time can be provided. Their germicidal action is too slow, however, to be of much value for in-plant chlorination.

CHLORINE DIOXIDE

Chlorine dioxide (ClO_2) is usually prepared by injecting chlorine gas into an acidified solution of sodium chlorite. A yellow-green solution of chlorine dioxide will result and can then be metered into water systems. The solution is not stable and must be used shortly after generation. Recently a manufacturer has made available a stable 10 percent solution of chlorine dioxide.[14] This improvement may enhance future uses of chlorine dioxide.

Chlorine dioxide does not combine with ammonia to form amines, nor does it combine with phenol type compounds. Instead, chlorine dioxide will oxidize phenols, as well as manganese, iron and other taste or odor producing compounds. It is a vigorous and effective oxidizing agent, greater than chlorine. Chlorine dioxide is regarded as being similar to chlorine in its efficiency in the destruction of bacteria and other microorganisms. It appears that chlorine dioxide will maintain a residual in the presence of organic matter for longer periods than chlorine.[15]

BREAK-POINT CHLORINATION

When small amounts of chlorine are added to water under controlled conditions, the first increments of chlorine are used up in satisfying the chlorine demand of the water. At the same time, chlorine loosely combines with nitrogenous matter present to form chloramines or other chloro-nitrogen compounds. As additional chlorine is added, a free residual appears. This residual gradually increases until it reaches an apparent maximum concentration, determined by the physical and chemical nature of the water. Beyond this point, oxidation reactions occur between further incremental additions of free chlorine and the chloro-nitrogen compounds. The measurable free chlorine residual will decrease by the amount necessary to completely oxidize the chloro-nitrogen compounds. Further additions of chlorine beyond this point will result in a second rise in free chlorine concentration which increases almost in direct proportion to the rate of chlorine application. It is this persisting residual which makes in-plant chlorination of value. The point after the first rise in concentration at which the free residual reaches its lowest level is known as the "break-point" (see figure IV-13). Break-point chlorination, then, is the practice of maintaining chlorine residuals beyond this point.

CHLORINE AS A GERMICIDE

Chlorine hydrolyzes in dilute water solutions as follows:

$$Cl_2 + H_2O \rightleftharpoons HCl + HOCl \qquad \text{(Equation 1)}$$

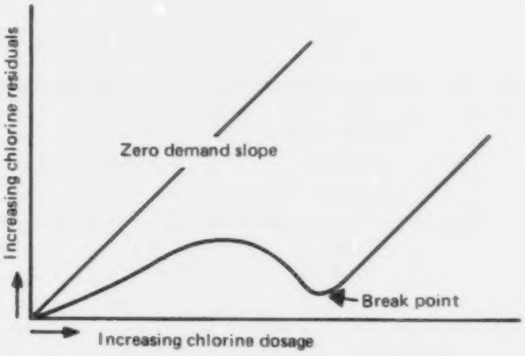


Figure IV-13. Break-point curve.

Hypochlorous acid (HOCl) readily dissociates to form hydrogen ions and hypochlorite ions:

$$HOCl \rightleftharpoons H^+ + OCl^- \qquad \text{(Equation 2)}$$

It is this undissociated hypochlorous acid that is primarily responsible for the destruction of microorganisms. Therefore, the germicidal properties of gaseous chlorine, calcium hypochlorite and sodium hypochlorite are attributable to the formation of HOCl when these compounds are dissolved in water. Generally, the rate at which organisms are killed is directly proportional to the concentration of hypochlorous acid. The proportion of HOCl which exists in solution is, in turn, determined by the pH, temperature and organic content of the water being chlorinated. Each of these factors has an effect on the equilibrium of Equations 1 and 2.

Effect of pH

At levels below pH 2, the reaction depicted in Equation 1 shifts to the left and most of the dissolved chlorine exists as Cl_2. Between pH 2 and pH 7, the predominant form is HOCl. Above pH 7, the equilibrium of Equation 2 shifts to the right until almost all of the chlorine exists as OCl^- at pH 8.5. This latter form of chlorine is a poor germicide.

Under practical conditions, the first reaction (Equation 1) goes to completion; that is, all the chlorine reacts to form the acids. Therefore, the critical consideration is the concentration of hypochlorous acid as determined by the pH, especially within the range of 7.0 to 8.5.

When chlorine gas reacts with water, both hydrochloric and hypochlorous acids are produced (Equation 1). The net result is a decrease in the pH as chlorine dosages are increased. However, when calcium hypochlorite is dissolved in water, the reaction products are hypochlorous acid, calcium chloride and calcium hydroxide. Similarly, dissolution of sodium hypochlorite produces hypochlorous acid, sodium chloride and sodium hydroxide. The amount of hypochlorous acid produced by the reactions of the hypochlorites is only sufficient to neutralize half the alkali formed so that free alkali results. This free alkali raises the pH and in turn reduces the amount of HOCl produced, thus lowering the germicidal power. This effect is clearly demonstrated by investigative results which are summarized in table IV-9. The results show that a sodium hypochlorite solution which contains 5 ppm total residual chlorine requires 2-1/2 times as long to kill all the yeast cells as does a 5 ppm chlorine gas solution. The pH factor becomes critical as the concentration of hypochlorite is increased to high levels. For example, a calcium hypochlorite solution of 25 ppm has a pH of 9.35, a 100 ppm solution has a pH of 9.75, and a 1,000 ppm solution has a pH of 11.10. At these high pH levels, the concentration of HOCl produced in relation to chlorine dosage is negligible.

Table IV-9.—*Comparison of killing power of hypochlorites and gaseous chlorine*[16]

Chlorine compound	Total residual chlorine (ppm)	pH[a]	Time required to kill 99.9% of cells[b]
Chlorine gas	5.00	7.0	1 minute
Calcium hypochlorite	5.00	7.4	2 minutes
Sodium hypochlorite	5.00	7.6	2.5 minutes

[a] The pH of the unchlorinated water was 7.2.
[b] Test organism was a nonsporulating yeast.

Effect of Temperature

It has been generally found that the time required for a given chlorine concentration to kill 99% of the bacterial cells in a solution is reduced by about 50% for each 18°F (10°C) rise in temperature. This is illustrated in table IV-10.

Table IV-10.—*The effect of temperature on sporicidal properties of calcium hypochlorite solutions*[16]

Type of *Cl. botulinum* spores used[a]	Time to destroy 99.99%, min.[b]		
	25°C	15°C	5°C
62 A	6	15	35
213 B	6	20	40
Saratoga E	4	10	24

[a] 1×10^4 spores/ml.

[b] 4.5 ppm free available chlorine, pH 6.5 (buffered).

Temperature also affects the solubility of chlorine in water as shown in table IV-11. This is unimportant for normal in-plant chlorination practices since chlorine is theoretically soluble to the extent of 2,200 ppm at 176°F. However, chlorine is rapidly reduced to an ineffective level as the temperature approaches the boiling point.

Table IV-11.—*Solubility of chlorine in water at different temperatures*[17]

Temperature		Maximum % chlorine dissolved
°C	°F	
0	32	1.46
10	50	0.98
20	68	0.72
30	86	0.56
40	104	0.45
50	122	0.39
60	140	0.32
70	158	0.27
80	176	0.22
90	194	0.12
100	212	0.00

Effect of Organic Matter

Small amounts of certain organic compounds in the water rapidly reduce the free residual chlorine, as shown in table IV-12. The type of organic matter is an important factor. Dissolved sugars and starches apparently have little effect on the free chlorine residual, while proteins and other nitrogenous compounds definitely reduce it and thus decrease its germicidal effect. The reaction between chlorine and nitrogenous organics produces chloro-nitrogen compounds, most significantly the chloramines. These are measured as combined residual chlorine. As previously noted, chloramines exert germicidal activity, but with greatly reduced effectiveness. Filtering reused water in a pea cannery to remove suspended matter only slightly reduces the chlorine demand of the water indicating that in this case, the soluble organic matter was responsible for the loss of

Table IV-12.—*Effect of organic matter on concentration of free chlorine residual in water*[18]

	Concentration of free chlorine ppm		
Time in minutes after chlorine added	No organic matter	0.5 ml tomato juice per liter of water	1.0 ml tomato juice per liter of water
1.0	5.00	4.20	3.45
3.0	4.95	3.70	2.65
6.0	4.95	3.45	1.95
9.0	4.92	3.20	1.60
12.0	4.90	3.00	1.50

free residual chlorine. Suspended matter may, however, protect bacterial cells from chlorine contact, thereby indirectly reducing the germicidal effectiveness of the solution.

IN-PLANT CHLORINATION

In-plant chlorination is defined as break-point chlorination of all water entering the plant, as well as water reused within the plant, to a degree where a persisting residual occurs. This practice provides a continuous application of germicidal chlorine to food preparation equipment, with the result that bacterial counts are reduced, slime formation is prevented, odors are avoided, and the time required to accomplish a satisfactory cleanup is shortened.

RECOMMENDED CHLORINE LEVELS

Free chlorine residuals of 2-7 ppm, measured at the point of water application to equipment, are recommended. If the operations are light, such as with only one shift, satisfactory control may be maintained by the lower concentrations, whereas during heavy or continuous operation higher concentrations may be required. An increase to free chlorine residuals of 10-20 ppm is recommended for cleanup purposes. This serves to give an effective germicidal treatment to all equipment in the plant.

EFFECT ON FOOD QUALITY

The effects of chlorine on the flavor of fruits and vegetables have been studied, and the results are summarized in table IV-13. Of the products tested, the flavors of apples, pears, cling peaches, figs, strawberries and yams were most susceptible to chlorine. However, when unchlorinated water was used for syrups and brines, off-flavors did not develop at chlorine concentrations recommended for in-plant chlorination. Tests on these products showed that a chlorine concentration of 5 ppm has no effect on color or ascorbic acid content.

EFFECT ON CANS AND EQUIPMENT

Chlorine is corrosive to common metals as shown in table IV-14. However, at low concentrations such as are used for in-plant chlorination (2-5 ppm), it does not noticeably corrode either cans or equipment under ordinary conditions. This conclusion is based on years of experience by many canners using in-plant chlorination. Although chlorine effectively prevents slime formation, corrosion does occur in this situation and is most severe under slime deposits. Even the high concentrations (10-20 ppm) used for cleanup do not generally produce significant corrosion because the contact time is short. However, while corrosion attributable to chlorination is not normally a problem, its possibility should not be completely ignored. If can cooling water contains sulfates

Table IV-13.—*Effect of chlorine treatment on flavor of canned foods*[19]

Product	Lowest concentration which produced off-flavor when 2, 5, 10 and 50 ppm of chlorine were added	
	Partial treatment. Chlorination of all water except brines & syrups Chlorine, ppm	Complete treatment. Chlorination of all water including brines & syrups Chlorine, ppm
Applesauce, Rome Beauty[a]	10	5
Applesauce, Gravenstein[a]	(None at 50)	10
Apricots, halves unpeeled	(None at 50)	50
Apricots, whole peeled	(None at 50)	50
Asparagus, all green	50	50
Beans, green cut	50	10
Beans, green limas	50	10
Beans, with pork (recanned)[a]	–	50
Beets, red sliced	50	10
Carrots, sliced	(None at 50)	10
Carrots, pureed[a]	(None at 50)	50
Cherries, Royal Anne	(None at 50)	50
Corn	–	(None with 15)
Figs, whole Kadota	50	5
Grapefruit juice (recanned)[a]	–	50
Orange juice (recanned)[a]	–	50
Peaches, clingstone halves	(None at 50)	5
Peaches, Elberta halves	(None at 50)	10
Peas	–	(None with 10)
Pears	50	2 to 5
Pineapple juice (recanned)[a]	–	10
Potatoes, sweet, solid pack[a]	(None at 50)	50
Pumpkin, solid pack[a]	(None at 50)	50
Prunes, Italian	(None at 50)	10
Spinach	50	10
Strawberries, whole	(None at 50)	5 to 10
Tomato juice[a]	–	10
Vegetable juice cocktail (recanned)[a]	–	5
Yams, syrup pack	–	5

[a] Chlorine added directly to the product.

or chlorides, the addition of chlorine increases the tendency toward can corrosion. In this instance, the addition of a corrosion inhibitor may be necessary.

Table IV-14.—*Effect of chlorine on metal and other surfaces*

Material	Effect of chlorine solutions		
	5 ppm	100 ppm	1,000 ppm
Glass, earthenware, silver[a], tantalum, most precious metals, bitumastics (tar), hard rubber	None	None	None
Soft gum rubber, fabrics, concrete	None	None	Disintegrates
Wood	None	None	–
Iron, steel, stainless steel, copper, brass, aluminum, tin	None	Corrodes[b]	Corrodes

[a] Protection of silver is due to formation of silver chloride and if this is removed by abrasion, corrosion will result.

[b] Corrosion occurs if application is continuous. A periodic application of a few minutes contact may have very little effect. The lower the pH, the more corrosion will result.

COOLING WATER CHLORINATION

When cooling water is reused or has a high bacterial content, chlorination is advisable. The use of chlorinated water in can coolers will help to prevent spoilage associated with recontamination. When cans are to be processed in retorts or continuous cookers, the cans should be washed or rinsed after filling and sealing to reduce the amount of organic matter which might be carried into the cooling system, thereby minimizing the chlorine demand.

Cooling Towers

Reclaimed water that is cooled by passage over a cooling tower may become highly contaminated with microorganisms and rechlorination will usually be necessary. Sufficient chlorine should be added as the water leaves the tower for use in the plant such that a free residual of approximately 0.5 ppm is measurable in the water as it drips from the tower at the end of the cycle. This treatment should be accompanied by screening to remove any large foreign materials. The cooling tower should be subjected to direct chlorination at 4-5 ppm for a few hours every week or two to eliminate more resistant microorganisms which may gradually develop (see figure IV-3).

Tank, Canal, and Rotary Continuous Coolers

Bacterial counts may rapidly build up to high levels in tank, canal or continuous rotary coolers unless the water is chlorinated. A free chlorine residual of at least 0.5 ppm at the discharge end of the cooler is recommended. When in-plant chlorination is practiced, the 5 ppm residual carried in the cooler inlet water is often sufficient to maintain the necessary 0.5 ppm at the discharge end of the cooler without additional chlorination.

Application of Chlorine Compounds

Chlorination of cooling water may be accomplished with either gaseous chlorine or hypochlorites. Either automatic or manual feed equipment may be used, but precise control of chlorine feed rates is possible only with automatic chlorinators. The same precautions apply for these installations as described under in-plant chlorination with gaseous chlorine.

For cooling canals and open coolers, hypochlorites are frequently used. These may be metered into the system with a chemical solution feed pump or, if no other means are available, by a drip feed mechanism. Drip feed equipment is satisfactory for applying sodium hypochlorite solutions. However, calcium carbonate deposits which form from calcium hypochlorites may clog drip feed equipment, thereby impairing controlability. Calcium hypochlorite solutions should be mixed several hours before use to allow the carbonate deposits to settle out. Pumps are advisable for addition of calcium hypochlorite solutions.

CHLORINATION OF WATER REUSED FOR OTHER THAN COOLING

When reusing water in food preparation departments, the best and safest method is the counterflow principle, with successive uses of the water in reverse order to the flow of the product through the plant. Fresh water is used for the final washing or fluming of the product prior to canning. The second or third uses may be for fluming or washing at intermediate stages in the preparation, and the last use for washing or pumping the raw product as it enters the preparation lines. The exact details of such a system must be worked out for each cannery since no two plants handle a given product in exactly the same manner. Guidelines were previously discussed in the section titled The Counterflow Water Reuse System.

In a counterflow system, water is collected in a separate tank after each use and should be rechlorinated at this point prior to reuse. Since the chlorine demand of the water will vary after each use, different amounts of chlorine must be added to each tank. One of two rechlorination systems may be used.

1. Small, cylinder-mounted chlorinators may be provided at each collection tank of the counterflow system. Each chlorinator may then be independently adjusted to provide the chlorine feed rate required to maintain the desired chlorine residual concentration. This system is also suitable for chlorination of water recirculation systems.

2. A single chlorinator, separate from the fresh water in-plant chlorinator, may be used to provide a concentrated chlorine solution for the counterflow system. The chlorine gas may be injected into a header pipe to generate the concentrated solution which can then be distributed to the collection tanks. The chlorine solution should be supplied to each tank through individual adjustable valves, thereby providing control of feed rates and chlorine residuals within each tank. A period of experimentation will be necessary to determine the appropriate feed rates for each valve and for the chlorinator.

   All components of this arrangement must be constructed from chlorine-resistant materials which are available from chlorine manufacturers. The concentrated chlorine solution supplied to each tank must be added below the water surface within the tank to prevent liberation of chlorine gas into the atmosphere around the equipment.

A minimum chlorine residual of 5 ppm should be maintained in fresh water added to a reuse system. However, the chlorine will combine with the organic matter present in the system, thereby necessitating rechlorination prior to reuse. Experience has shown that the most economical yet effective chlorine dosage for reused water is that which produces a free residual of 0.10 to 0.50 ppm when measured at the end of the subsequent use by the orthotolidine flash method. This assures complete satisfaction of the chlorine demand of the water and provides a fairly high total residual. Because of the extended period in which the water is used, the total residual exerts enough germicidal activity to prevent the reproduction of microorganisms.

IODOPHORS

Chemically, iodine is one of the halogens, along with chlorine, fluorine and bromine. It is a heavy, bluish-black solid at room temperature, in contrast to yellow, gaseous chlorine. It has a high vapor pressure and sublimes readily, with vapors showing a characteristic violet color. It is only slightly soluble in cold water (one part in 3450 at 20°C), but its solubility increases as the temperature of the water rises. In contrast, chlorine is more soluble but unlike iodine, its solubility decreases as the temperature increases. Aqueous solutions of free iodine show a characteristic yellowish color when dilute, and reddish-brown when concentrated.

FORMULATION AND PROPERTIES

An iodophor is a mixture of iodine and a carrier. The carrier is a compound that greatly increases the solubility of iodine in aqueous systems while decreasing its chemical reactivity with materials other than microorganisms. Surface-active agents (surfactants) or water-soluble polymers may serve as carriers. A number of anionic, cationic and non-ionic surfactants solubilize iodine. The various agents differ from each other in their ability to solubilize iodine and in their stability, reactivity in terms of the amount of iodine liberated, viscosity, foaming, detergency, wetting action and other properties of the resulting iodophor.

Reeves and Tilley[20] reported that commercial iodophors today are almost exclusively complexes of iodine and non-ionic surfactants. Non-ionics display their activity in hard waters and under a wide range of pH conditions which usually render ionic compounds ineffective. Moreover, these compounds are electrically neutral and thus compatible with electrolytes and other surfactants. These characteristics are of great value under conditions encountered in practical applications. Of the non-ionics available, members of the alkylphenoxypolyglycol ether group are in widest use.

GERMICIDAL ACTIVITY

Mode of Action

Studies by various workers indicate that free iodine, in the diatomic form I_2, is the agent responsible for the germicidal action of the iodophors. Russell[21] reported that Allawala *et al* have found that the time required to achieve a 99% reduction of bacterial cells and spores was a function of the concentration of free iodine, despite the presence or absence of added surfactant. Bogash[22] reported that the time required to destroy *M. tuberculosis* was reduced by 50% when the concentration of available iodine was doubled (from 25 to 50 ppm). Others have found that when the chemical reaction occurring between iodine and *E. coli* was studied, only 10% of the absorbed iodine was found to be retained by the cells. The other 90% reappeared as iodine in the supernatant fluid. This was interpreted as indicating the occurrence of an oxidative reaction. It was not possible to decide which of these two types of reactions was responsible for the lethal effect of iodine. Trueman[16] suggested that both probably play a part.

The Effect of pH

In aqueous solutions, iodine can exist in several forms as a result of a hydrolysis reaction with water. Unlike chlorine solutions, it is the free element (I_2) which is responsible for the germicidal action of iodine solutions. The pH of the solution determines the form of iodine present. Consequently, iodophors (as with chlorine) exhibit maximum germicidal activity at an acidic pH. For this reason, suitable buffering agents and certain acids are used in the formulation of most iodophors to maintain the proper pH and provide a more stable product, especially in the presence of organic impurities.

Iodine in neutral aqueous solutions is present almost completely as the effective, diatomic molecule. Therefore, increasing the acidity can increase the iodine concentration only slightly by favoring the equilibrium. It seems unlikely that this small quantity would significantly influence the overall germicidal efficiency. It has been speculated that acid may increase the penetrability or reactivity of free iodine with the organic matter of the microbial cell.[23]

Excess alkalinity tends to lower the germicidal efficiency of iodine solutions. When low concentrations of available iodine are used, solutions will have little or no germicidal activity at pH levels higher than 8.0. At such high pH levels, available iodine will be converted to the inactive iodide and iodate forms.

Effect of Organic Matter

The effect of organic matter on the germicidal properties of both chlorine and iodine solutions was studied by several workers. Evans[24] and Wilson[23] reported that the inhibitory action of organic matter was significantly less in iodine solutions than in chlorine solutions. Parker[25] indicated that in the presence of 5% skim milk and at 45°C, the destruction of *Staphalococcus aureus* within 30 seconds required 10 ppm of available iodine, compared to 35 ppm of available chlorine (hypochlorite).

Iodine does not combine with ammonia to form iodamines, but rather oxidizes the ammonia. It also oxidizes phenols rather than combine with them to form objectionable organic compounds. Consequently, it has been concluded that in the presence of organic matter, low iodine residuals should be more stable and therefore persist longer than corresponding residuals of any of the other halogens.

Effect of Temperature

The germicidal efficiency of iodophors increases as the temperature increases. It is reported that the concentration of available iodine required to kill a suspension of *Staphalococcus aureus* within 30 seconds was 5 ppm at 45°C and 20 ppm at 5°C. Table IV-15 shows results reported by Wilson[23] in terms of ppm of free iodine required to kill a number of different organisms at two different temperatures at pH 7.5.

CORROSIVITY OF IODOPHORS

The corrosive effect of elemental iodine on many metals is reported to be greatly reduced when iodine is complexed in iodophors. At the recommended concentrations, iodophors have no corrosive effect on tinned and stainless steel surfaces. However, iodophors will tarnish silver, silver plate and copper. When iodophors are used to sanitize aluminum contact surfaces, gradual darkening, but no pitting, may also be observed.

Table IV-15.–*Effect of temperature on the germicidal action of iodine solutions at pH 7.5*[23]

Test organism	Average ppm I_2 required to kill organisms in 1 min.	
	At 2-5°C	At 20-26°C
E. coli C-36	2.0	0.69
A. aerogenes	0.9	0.6
S. typhosa P-10	0.87	0.4
S. sonnei I P-9	2.47	0.6
S. fecalis E-40	2.37	0.7

POTENTIAL USE FOR THE DISINFECTION OF CAN COOLING WATER

Unlike chlorine and chlorine-containing compounds, iodophors have not been considered for the disinfection of potable water until very recently. Therefore, practical experience relative to their use in can cooling systems is extremely limited. Only in recent publications are references given indicating the advantages of iodine-liberating compounds as disinfectants or sanitizers in restaurants, bottling plants, dairy farms and plants, and fruit and vegetable packing and canning plants.

A recent article indicated that a specially-formulated iodophor was used by a cannery in lieu of chlorine for the disinfection of can cooling water and in can-sealing operations[26]. It was reported that this treatment achieved the required sanitary conditions in the cooling water and produced bright and shiny cans free of rust and water spots. In this experiment, a proportioning feeder was used to furnish a constant level (0.1 to 0.3 ppm) of available iodine in the discharge exit of the can cooler. These results were confirmed in a study at another plant.[27]

OZONE

Ozone has a characteristic pungent odor, thought by some to be refreshing in low concentrations. It is colorless at room temperature and condenses to a dark blue liquid. Liquid ozone is very unstable and will readily explode. Concentrations of ozone in air-oxygen mixtures above 30% are also easily exploded. Ozone may react with activated carbon to form explosive end products. Ozone is considered one of the most powerful oxidizing agents, attacking almost all organic compounds. It has an oxidation-reduction potential of 2.07 volts, compared to 1.49 for hypochlorous acid and 0.75 for chloramine.

The density of ozone is 1.5 times that of oxygen and is about 10 times more soluble in water. However, because of a much lower available partial pressure, it is difficult to obtain a concentration in water of more than a few parts per million under normal conditions of temperature and pressure. Ozone is unstable in water, having an effective half-life of about 20 minutes. Its decomposition is accelerated by neutral salts and hydroxyl ions. Therefore, it must be produced on the site where it is to be applied.

Ozone can be produced by one of three techniques: (1) electrical discharge, (2) electrolysis of perchloric acid, or (3) ultraviolet irradiation. Of these, electrical discharge is the only practical and economical method for large scale ozone production. The process, as shown in figure IV-14, involves the passage of dry air (or oxygen) between two electrodes across which an alternating high-voltage potential is maintained. To insure the conversion of an optimum part of the oxygen into ozone, a uniform blue-violet glow discharge is maintained by inserting a dielectric material between the electrodes.

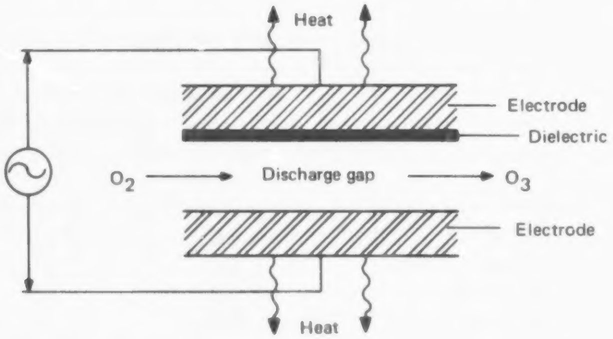


Figure IV-14. The process of ozone generation.

GERMICIDAL ACTIVITY

In a recent investigation, Häufele and Sprockhoff[28] studied the germicidal effect of ozone on the vegetative cells of a number of bacterial species. *E. coli, S. marcescens, Ps. aeruginosa* and *Staph. auerus* (ATCC 6538) were used. They reported that complete destruction of these microorganisms required between 0.05 and 0.7 ppm ozone, depending upon the density of the test organism and the contact time. The only exception was the *Staphylococci* which required 3-5 ppm ozone for the complete inactivation. It is believed that the cluster-like growth of the *Staphylococci* affects the penetrability of ozone. The results of this part of the study (table IV-16) correlate with those cited in several other reports, especially those cited for *E. coli.*

Higher ozone concentrations and longer contact times are required for the destruction of bacterial spores. Venosa[29] reported that in water containing *Cl. perfringens* at a concentration of 2 x 10^3 spores per milliliter, and maintained at pH 6.0 and a temperature of 24°C, complete kill of the spores was achieved after a contact time of 15 minutes with 0.25 ppm ozone, or after 2 minutes with 5 ppm. Broadwater[30] found the spores of *B. cereus* and *B. megaterium*, which exhibit the same degree of resistance, were from 10 to 15 times more resistant to ozone than were their vegetative cells. Based on the widely accepted theory of protoplasm oxidation, he explained that the greater resistance of spores probably is a result of the protection afforded the protoplasm by the spore's thick, multilayered cortex and the exosporangium, whereas the protoplasm of the vegetative cell is protected only by a cell wall.

The germicidal efficiency of ozone in aqueous solutions is influenced by several factors including the presence of impurities, concentration of ozone in solution, contact time, pH and temperature of the solution, and the initial microbial load of the water. The magnitude of influence, however, differs significantly among these factors. For example, it has been reported by many research workers that ozone disinfection is mainly a function of the concentration of ozone, contact time, and the presence or absence of impurities, either organic or inorganic. Few investigators have added temperature to these three factors.

Table IV-16.–*Germicidal action of ozone against* E. coli, S. marcescens, *and* Ps. aeruginosa *in tap water*[28]
[Temperatures between 11.7°C and 13.5°C]

Organism	Initial load per 100 ml.	O_3, ppm	Count/100 ml. after 3 min.	Count/100 ml. after 1 hr.
E. coli	3 x 10^7	0.16	0	0
		0.13	2	0
		0.08	11	6
		0.02	– Not Counted –	
S. marcescens	4 x 10^7	0.70	2	0
		0.52	6	1
		0.38	16	3
		0.22	N.C.	9
Ps. aeruginosa	1.2 x 10^7	0.38	0	0
		0.29	2	1
		0.18	6	1
		0.12	138	96

The Effect of Concentration

One of the major differences between chlorine and ozone disinfection is the correlation between the concentration of the agent used and the germicidal efficiency exhibited. As shown in figure IV-15, the germicidal efficiency of chlorine is directly proportional to its concentration, whereas with increasing concentration of ozone, there is little improvement until a *critical concentration or dose is reached*. Subsequent to this critical or "threshold" dose, as it is sometimes designated, the germicidal action is very rapid and is proportional to the concentration of ozone in the water. Broadwater[30] obtained similar "all or none" results for vegetative and spore cells. The ozone threshold for spore destruction was much higher than for vegetative cells.

The Effect of Impurities

The critical concentration of ozone in an aqueous solution is a function of the ozone demand of the water. The demand of the water must be satisfied before the solution exhibits a significant

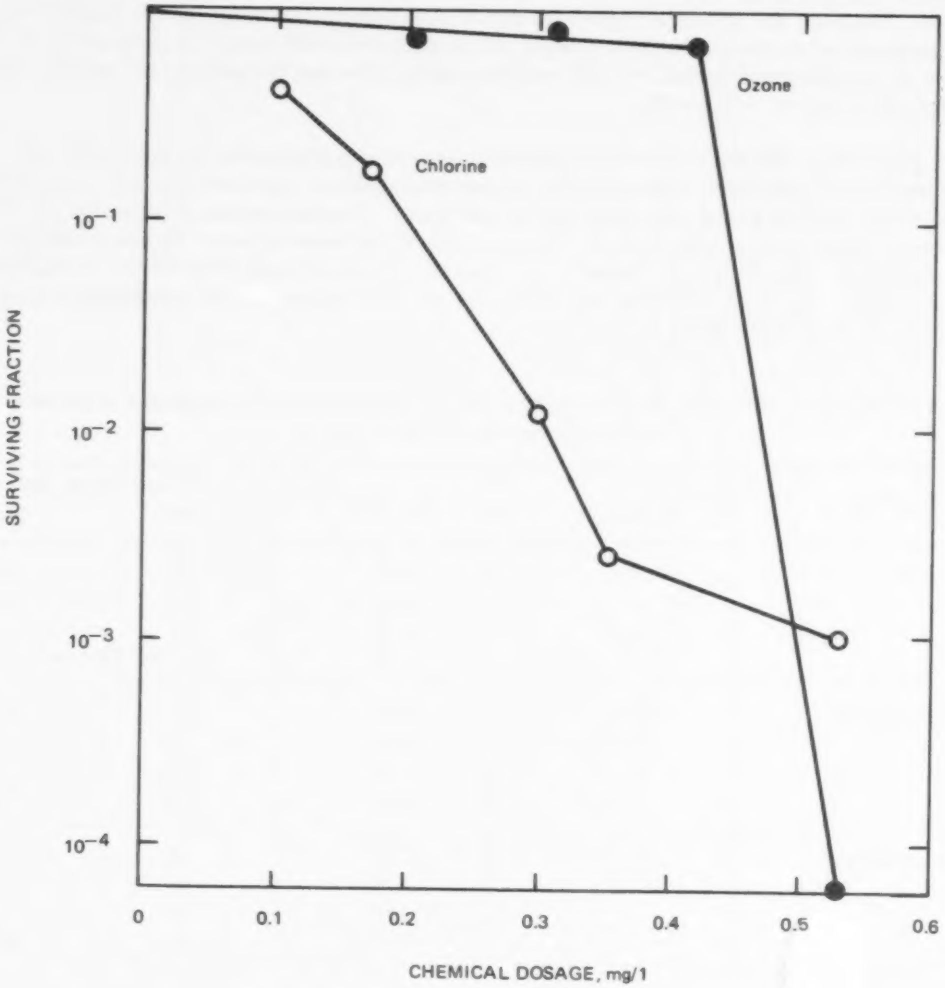


Figure IV-15. Germicidal activity of ozone and chlorine.[30]

germicidal action. Because of its extremely high oxidation potential, ozone reacts rather readily with many inorganic and organic substances present in the water. Therefore, large doses of ozone may be required in solutions that contain oxidizable constituents before acquiring a germicidally-active ozone residual. However, ozone does not readily oxidize all compounds. Some easily oxidizable substances (such as simple carbohydrates) do not react readily with ozone. Yet ozone causes complete destruction of phenolic compounds present in water.[30] Destruction of phenol by ozone has been reported to require a dose of about 1.2 ppm for each 0.2 ppm of phenol. Ozone treatment also results in complete oxidation of ammonia and other nitrogenous compounds.

The Effect of Temperature

The germicidal properties of ozone are generally reported to be insignificantly affected by temperature changes. However, Bringmann[31] observed that the time required to achieve 100% kill of 6 x 10^4/ml. *E. coli* by 0.1 ppm ozone in water was reduced from 5 seconds to less than one second when the temperature of the water was increased from 22°C to 37°C. Venosa[29] reported that Gabovich in Russia had recently studied the effect of physico-chemical properties of water on the germicidal effectiveness of ozonation. It was pointed out that the attainment of a desired bactericidal effect for an increase in water temperature from 4-6°C to 18-21°C resulted in a 60% and 20% increase in gross and net ozone consumption, respectively. These findings support those of Fetner[32] and others; that is, the decomposition of ozone to oxygen is temperature dependent and, therefore, the lower the ambient temperature, the greater the effectiveness of ozone.

CORROSIVITY OF OZONE

In a pilot plant study conducted by Kirk *et al*,[33] a variety of materials were used in manufacturing the reactors, tanks, pumps and pipes carrying both the dry gas and the wet spent gas. Mild steel, aluminum, stainless steel, and polyvinyl chloride (PVC) were used. After nine months of continuous operation, no corrosion problems had become evident with any of these materials. Diaper[34] also claims that when ozone is used for taste and odor control, it appreciably reduces the carbon dioxide content of the water with the side effect of reducing corrosiveness.

If the moisture content of the air used in ozone production exceeds a certain limit (dew point of -50°C), not only will ozone yield be reduced, but corrosion problems will also be encountered. It has been pointed out that at higher moisture content, higher concentrations of nitrogen oxides (especially N_2O_5) are produced by the reaction between ozone and the nitrogen present in the gas stream. Nitrogen pentoxide (N_2O_5) combines with moisture to form nitric acid, which is highly corrosive to metal surfaces and causes extensive damage to the dielectrics of the generator. For this reason, drying of air is one of the most important steps in ozone production.

PHYSIOLOGICAL EFFECTS OF OZONE

One objection that has been raised to using ozone is its toxicity and potential danger. While ozone is definitely toxic, there are factors which reduce the immediate danger to individuals working with it. A Maximum Allowable Concentration (MAC) over a period of time has been established by the American Council of Governmental Industrial Hygienists as 0.1 ppm by volume of air for continuous exposure under normal working conditions. As shown in figure IV-16, exposures at higher concentrations can be tolerated for shorter periods. The clinical effects immediately recognized from inhaling ozone range from headaches and dryness of the mucous membranes of the mouth, nose and throat, to more serious changes such as functional derangements of the lung, pulmonary congestion and edema when exposure to ozone continues.

The threshold odor level of ozone is 0.01-0.02 ppm. This means that a person working near an ozone handling area should be able to detect the presence of ozone at concentrations far below the MAC. Since ozone is generated at the site of application and is not stored under pressure, any leakage from the system can be quickly stopped by simply turning off the electrical supply.

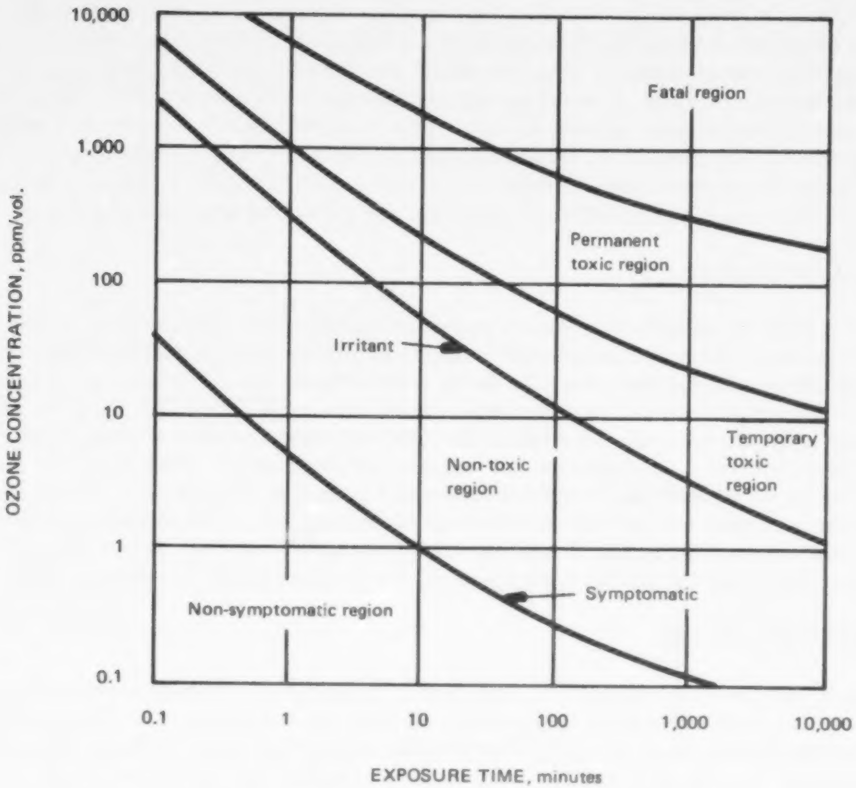


Figure IV-16. Toxicity of ozone.

COMPARATIVE EFFECTIVENESS OF SELECTED GERMICIDES

A laboratory study was conducted to develop information on the comparative germicidal (or more specifically, the sporicidal) effectiveness of various compounds which might be useful in can cooling systems. The organisms utilized in this study were *B. stearothermophilis* (NCA 1518), a thermophilic aerobe; *B. macerans*, a mesophilic aerobe; and putrefactive anaerobe 3679 (NCA). The study was limited to comparing the germicidal properties of various concentrations at two pH levels, pH 6.5 and pH 3.5, and at two temperatures, 25°C and 55°C. In all cases the sporicidal efficiencies of the tested compounds were enhanced by raising the temperature or by lowering the pH. Significant differences in effectiveness were noted between the selected germicides (figure IV-17).[35] For destroying *B. macerans* spores, ozone was found to be most effective with equal efficiencies at both pH levels. Chlorine's efficiency was increased at the lower pH with chlorine being an effective sporicide under all test conditions. Iodophors displayed the greatest dependence on pH and temperature. At the higher pH level or at the lower temperature, the iodophors were ineffectual in destroying spores of *B. macerans*. Similar results were noted for the other test organisms.

OTHER CHEMICAL AND PHYSICAL GERMICIDAL AGENTS

There are a number of chemical and physical agents, other than those described above, which possess germicidal properties. However, most of these are, for various reasons, unsuitable for use as water disinfectants. Briefly discussed below are a few chemicals (quaternary ammonium compounds, bromine and heavy metals) and physical processes (ultraviolet and ionizing irradiations) which may have application for this use.

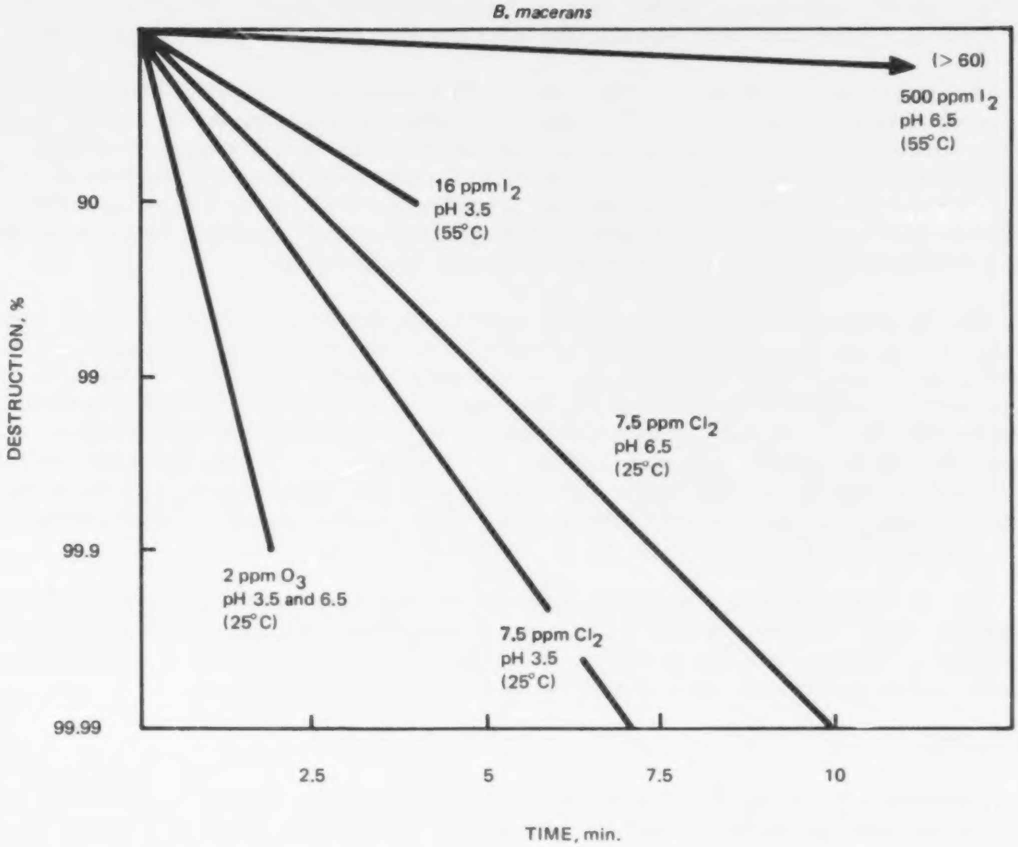
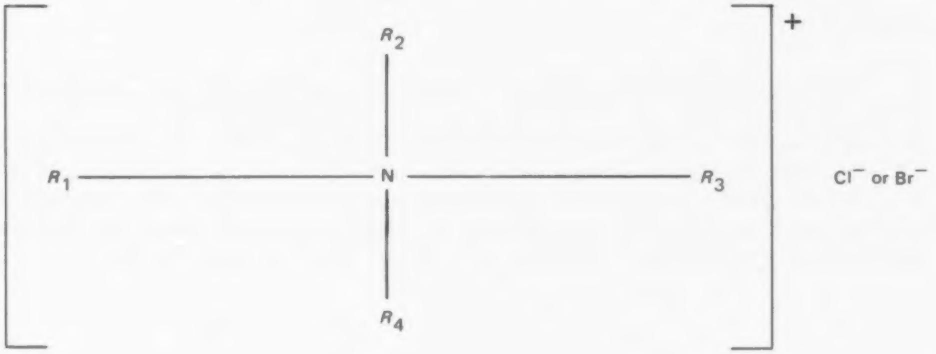


Figure IV-17. Comparative effects of the sporicidal properties of chlorine, iodophor and ozone.[35]

QUATERNARY AMMONIUM COMPOUNDS (QUATS or QAC's)

Quaternary ammonium compounds are cationic surface-active disinfectants having a general chemical structure as follows:



$$\left[\begin{array}{ccc} & R_2 & \\ & | & \\ R_1 - & N & - R_3 \\ & | & \\ & R_4 & \end{array}\right]^+ \quad Cl^- \text{ or } Br^-$$

where R_1 represents the long chain ($C_8 - C_{18}$) alkyl or alkylaryl groups or their derivatives; and R_2, R_3, and R_4 represent hydrogen, alkyl, aryl, or heterocyclic groups. A large number of compounds of this general class have been manufactured and their germicidal properties evaluated.

The mode of germicidal action of the quats is still a matter of controversy. Some investigators have reported that they interfere with the respiration system by inhibiting the enzymes of carbohydrate metabolism. Others have claimed that they cause leakage of the cellular constituents by lysis. Denaturation of cell cytoplasm and splitting of lipoprotein complexes throughout the cell (with the result that autolytic enzymes are able to act freely and uniformly with it) have also been indicated. Quats are effective against gram-positive and gram-negative bacteria. However, studies with *B. subtilis* spores indicate that quats are sporistatic, not sporicidal.

With the majority of the quats, the effect of pH on the germicidal activity is generally opposite that for chlorine and hypochlorite; that is, the activity increases with increasing alkalinity of the solution. In the presence of a moderate amount of organic matter, their action is affected to a lesser degree than that of hypochlorites and several other germicides. However, their effectiveness is sharply reduced in hard waters and by a number of incompatible compounds such as anionic wetting agents. Most of the difficulties encountered in hard water supplies can be avoided where quats are combined with nonionic wetting agents, sequestering agents, and alkaline detergent salts in detergent sanitizers. Generally, quats are heat stable and their effectiveness is increased with increasing temperature. They are relatively ineffective in very cold solutions.

The U.S. Food and Drug Administration, while not approving or disapproving the use of quats in sanitary practice, considers any food product containing these compounds to be adulterated under the provisions of Section 402(a)(1) of the Federal Food, Drug and Cosmetic Act. Bitter tastes are imparted to many food products contacted by quats.

BROMINE

Bromine is a heavy (Sp. Gr. = 2.94) dark reddish-brown liquid which melts at -7.3°C, boils at 58.78°C, and dissolves readily in water. It exhibits chemistry in water qualitatively similar to that of chlorine. It hydrolyzes to hypobromous acid (HOBr), ionizes to hypobromite ion (OBr^-), and reacts with ammonia to form monobromamine (NH_2Br) and dibromamine ($NHBr_2$), but does not form a stable tribromamine. The same degrees of ionization for HOBr occur at pH values about one pH unit greater than those of HOCl.

There are no known applications of bromine as a drinking water disinfectant. Because of the germicidal properties of bromamines, bromine has been used, on a limited scale, for the disinfection of swimming pool waters and certain industrial wastes. The strong tendency of bromine to form irreversible compounds with organic matter of unknown physiological effects, the high costs and difficulty of handling, and the toxicity and corrosivity of bromine are major factors deterring the use of bromine for purification of drinking water and wastewaters.

HEAVY METALS

Silver, copper, mercury, cobalt and nickel have been found to have significant germicidal properties. However, silver is probably the only heavy metal with any reasonable degree of efficacy, and probably the only one used for the disinfection of potable water. The use of silver for this purpose has been more popular in Europe than in the United States. The major disadvantages of employing silver for the disinfection of water are the high costs, the extensive water pretreatment required, the long contact time necessary, the resistance of certain microorganisms to the action of silver and the significant adverse effects of certain anions, low pH and low temperatures.

According to Section 141.11 of the interim drinking water standards (PL 92-523 Safe Drinking Water Act), the presence of silver in concentrations above 0.05 ppm shall constitute grounds for rejection of that supply as a source for drinking water.

ULTRAVIOLET IRRADIATION (UV)

Ultraviolet or short wavelength irradiation is customarily produced by low pressure mercury vapor lamps which emit a narrow band of radiant energy at 2537 Å (angstrom). At this wavelength, only 85% of the maximum germicidal effect on most bacteria, fungi and viruses occurs (maximum destruction occurs at 2560 Å). The germicidal action of UV radiation has been linked to the absorption of the energy by the nucleic acids in the cells which are consequently destroyed. Spores, cysts, and viruses are normally more resistant to UV inactivation than are vegetative bacterial cells.

The main disadvantages of UV disinfection of water are that the water to be disinfected must be thoroughly pretreated to remove all the organic and inorganic impurities; color and turbidity sharply reduce the efficiency of the treatment; no residual disinfecting capacity is provided; and treatment efficiency is not readily measurable.

IONIZING IRRADIATIONS

Ionizing irradiations, such as gamma and X-radiation, have been suggested as a potential means of water disinfection. However, little information is available on these applications. Gamma rays were found to be nearly one million times as powerful as UV radiation, which explains their greater penetrating capability and their high degree of effectiveness against spores and viruses. Their germicidal action is attributable to the direct ionization of the cell molecules, leading to death, and to the interaction of the radiation with the water producing unstable atoms and free radicals which may chemically react with organic molecules or cause secondary radiation effects in viable cells.

Complete disinfection of a wastewater may require dosages as high as several million rads. At such high dosages, a number of undesirable side effects may occur. This, together with the care required in applying this method of disinfection, would seem likely to restrict its use to items of high value per unit weight. Low dosages in the range of 50,000 to 1,000,000 rads are used to "pasteurize" surfaces of certain foods, and to inhibit the sprouting of potatoes and onions in storage.

C. WASTE PREVENTION

The preparation of fruits and vegetables for preservation by freezing, canning or dehydration generates enormous volumes of liquid wastes and solid residuals. The previous sections of this chapter dealt with water conservation techniques which can be employed to reduce the volume of fresh water taken into the plant and, subsequently, the hydraulic load discharged. But this does not solve the problem of organic pollutant production as the result of raw materials contacing water. To prevent this generation of waste, one must prevent raw materials from contacting water. Complete elimination of water is impossible, since fruit and vegetable processing operations inherently require the use of water. Therefore, one can only reduce the organic load in the discharge by minimizing product-water contact wherever possible.

The reduction of product-water contact can be achieved by varying the operating practices and by the use of newly developed food processing equipment. In recent years, the design of new equipment has included consideration of not only high rate of production, product quality, and ease of sanitation but also pollution abatement and energy demand.

Research and development work on food processing equipment of radically different concept and design has received increasing attention in the past five years. The long range goal of these programs is to develop equipment which will provide final products of acceptable quality and safety with substantially reduced generation of liquid wastes and/or with solid by-products generated in more manageable or utilizable form.

The following discussions identify some operating practices and process modifications which can be utilized with relative ease to prevent or minimize the generation of pollutants.

IN-PLANT HANDLING OF SOLID WASTES

Solid wastes from food canning and freezing operations generally fit into two categories: non-food refuse and food residuals. The first includes damaged cans or containers, packaging materials, broken glass, discarded paper, broken pallets, and other similar inert materials. The second category, which represents the major quantity of solid waste, includes all non-usable items of raw materials procured for processing, such as damaged and culled whole fruits and vegetables, seeds, stems, leaves, skin or peel, and other degradable materials which are removed in processing. Procedures for handling fruit and vegetable residuals significantly influence the characteristics of the plant effluent. Therefore, emphasis in the following paragraphs is placed on methods for handling fruit and vegetable wastes within a plant in a manner that will minimize the generation of water pollutants.

HANDLING METHODS

In-plant handling of fruit and vegetable processing residuals is not unlike the handling of raw products. As in the case of raw products, the residuals may be handled or transported in containers, by mechanical or pneumatic conveyors, hydraulically in flumes or, unlike raw products, in floor gutters. Containers which are commonly used include pans, barrels, bins or boxes, and portable metal hoppers. Mechanical conveyors include belts, vibrating troughs or tables, drag chains, and screw or auger conveyors. Pneumatic conveyors, which have recently been improved to handle bulk items are available either as positive or negative pressure systems.

The properties of solid waste (as determined by the size of particles, density, fluidity and quantity), as well as the physical layout of the processing plant, determine the method best suited for handling waste materials. In the interest of minimizing wastewater loads, hydraulic systems should be avoided whenever possible. Where such systems are unavoidable, reclaimed water (*never* fresh water) should be used. Alternate methods for handling residuals from various processing operations (figure IV-18) are discussed in the next section and summarized in table IV-17.

RESIDUALS FROM SPECIFIC OPERATIONS

In a recent survey of the canning and freezing industry,[36] information regarding current practices for in-plant handling of fruit and vegetable residuals was elicited (table IV-18). The frequency of handling food residuals in water was almost twice that of dry handling. Although residuals from some operations physically necessitate wet conveying (such as mud from washers or peel from chemical peelers), solid wastes from many sources can readily be handled dry.

CLEANING

Fruits and vegetables for processing are initially cleaned to remove soil, dust, microbial contaminants, and extraneous matter such as leaves, stems, and stones. The cleaning techniques include one or more of the following: dry screening, pneumatic cleaning, agitated water baths, water flumes or sprays. Mechanical means in cleaning fruits and vegetables may be limited by the inability to handle different sizes of material or by excessive damage to the product. The methods are described in the sections that follow.

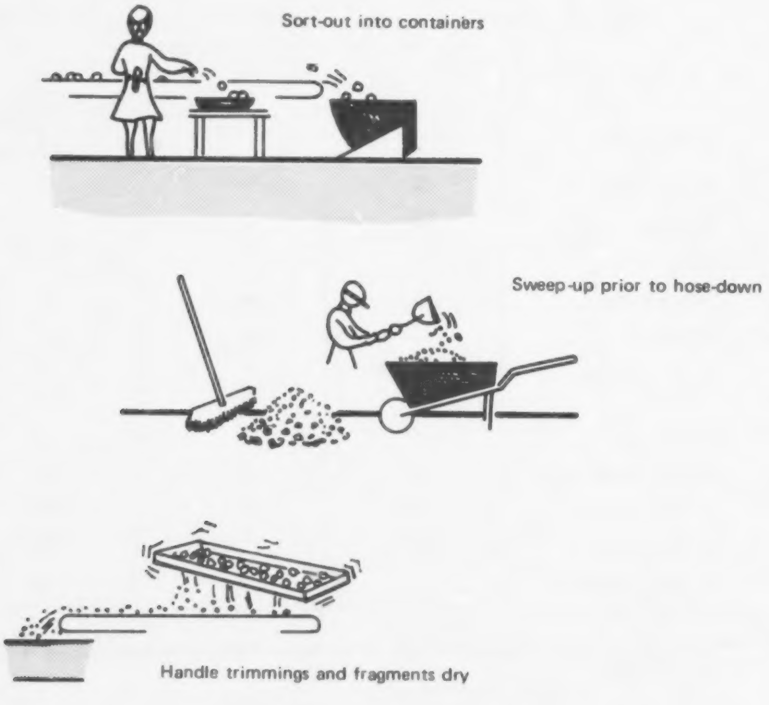

Sort-out into containers
Sweep-up prior to hose-down
Handle trimmings and fragments dry

Figure IV-18. Dry handling solid wastes.

Table IV-17.– *Methods suitable for in-plant handling of food residuals*

Source of residuals	Handling procedures							
	Container	Conveyors					Pneumatic	Hydraulic[a]
		Belt	Mesh	Drag	Screw	Vibrate		
Dry cleaning	X	X	X	X	X	X	X	
Washing	X		X					
Initial sort	X	X	X	X	X	X	X	
Size grading	X	X	X	X	X	X	X	
Trimming	X	X		X	X	X	X	
Cutting, slicing, dicing	X	X			X	X	X	
Peeling		X			X			X
Pitting	X	X		X	X	X	X	
Final sort	X	X		X	X	X	X	
Pulping, pressing	X	X		X	X	X	X	
Plant cleaning	X	X		X	X	X	X	

[a] separate pumping system

Table IV-18.– *In-plant handling methods for fruit and vegetable residuals*

Waste source	In-plant handling method[a]			
	Containers	Dry convey	West convey	Gutter
Dry cleaning	27	36	7	33
Washing	13	0	12	82
Initial sort	35	17	11	48
Size grading	15	40	10	36
Trimming	16	38	12	37
Cutting, slicing, dicing	11	42	7	40
Peeling	0	9	6	85
Quality grading	7	0	7	86
Pitting	7	15	78	7
Final sort	29	8	8	63
Pulping, pressing	16	39	6	51

[a] Percent each category reportedly used. Since two or more methods are used in many plants, the totals exceed 100%.

Dry Cleaning

Many products are initially "dry cleaned" to remove readily separable extraneous materials which are inadvertently mixed with the delivered produce. Equipment used for this purpose include revolving or vibrating coarse screens to remove sand from spinach and other leavy greens and dirt clods from root vegetables, roller conveyors to separate leaves from tree fruits, and air cleaners to remove loose husks and leaves from corn and vines from green beans and peas.

Materials removed in dry cleaning operations can readily be handled dry. When the quantity of material removed is relatively small, containers such as bins or portable hoppers can be used to accumulate the solid waste. If the material quantity is large, equipment should be provided to continuously remove the waste from the operation and to convey it to an appropriate on-site storage area. Belt, screw, and drag chain conveyors, as well as pneumatic systems, are quite suitable for most types of wastes removed in this operation. Provisions for dry handling these materials eliminate the need for transport water and will reduce the organic load (primarily the settleable and suspended solids content) which would be generated by hydraulic conveying.

In the case of tomatoes, a rubber disc unit[37] replaces the flumes and sprays used in conventional processes to remove tightly adhering smear soil (figure IV-19). This step supplants the long exposure to the turbulent action of water with a short exposure to the vigorous mechanical wiping action of soft rubber discs. The action of the discs moves the tomatoes through the unit, loosens and wipes off the soil, and throws the heavy soiled water into a tray located beneath the device.

Average wastewater characteristics using the rubber disc unit range from 1.8 to 3.2 tons of tomatoes per hour. COD from the dump tank (1.1 pounds/ton) was significantly larger than that from the disc cleaner (0.5 pounds/ton). The average residence time of tomatoes in the dump tank was 1-2 minutes, while the average residence time on the disc cleaner was 15-25 seconds. Table IV-19 gives data for several typical runs, for which only the final rinse sprays were used with the disc cleaner. Percent removals were obtained by measuring soil, total count and mesospores found on tomatoes sampled after the dump tank and after the disc cleaner, and comparing these values to those found on tomatoes sampled from the harvest bin.

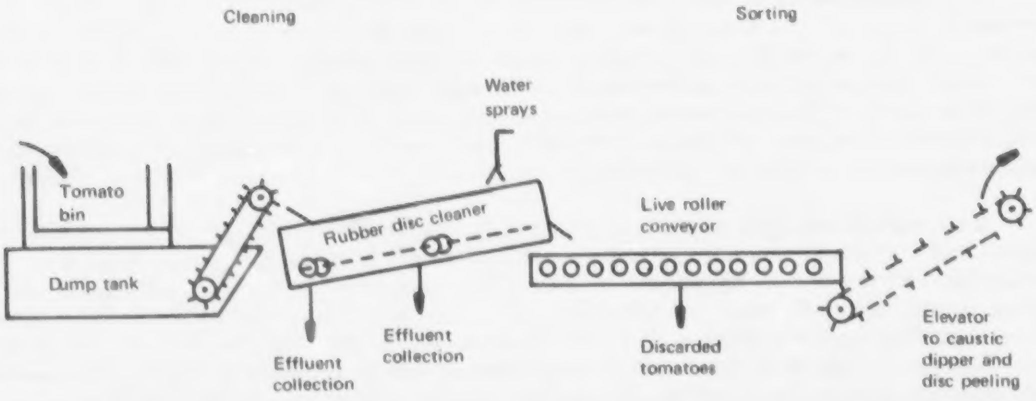


Figure IV-19. Pilot scale cleaning line.

Table IV-19.– *Soil, total bacterial count, and mesospore count on tomatoes at selected points in cleaning operations*[a]

Feed rate (tons/hr)	Location	Soil		Total count/ml		Mesospore count/ml	
		ppm	% Reduction	$(\mathrm{X}10^4)$	% Reduction	$(\mathrm{X}10^4)$	% Reduction
2.7	Harvest bin	70	–	7,000	–	2,400	–
	After dump tank	20	71	1,500	79	1,000	58
	After disc cleaner	0	100	130	98	32	99
2.5	Harvest bin	190	–	2,400	–	1,300	–
	After dump tank	50	74	1,300	46	300	77
	After disc cleaner	10	95	120	95	20	99
2.8	Harvest bin	510	–	400	–	27,000	–
	After dump tank	60	88	220	45	7,400	73
	After disc cleaner	0	100	40	90	1,900	93
3.1	Harvest bin	790	–	12,800	–	2,800	–
	After dump tank	210	73	2,100	84	1,400	50
	After disc cleaner	10	99	188	99	67	98
2.9	Harvest bin	2,990	–	78,000	–	8,500	–
	After dump tank	150	95	12,800	84	2,400	72
	After disc cleaner	10	99+	4,800	94	84	99

[a] Final rinse sprays over disc cleaner only

Cleaned tomatoes appeared free of contaminants, and industrial representatives stated that they compared well with tomatoes cleaned conventionally. No significant difference could be found between round and pear-shaped varieties of tomatoes in contaminant removal. Total soil removal was consistent over the feed range of 1.8-4.5 tons per hour and an initial soil load range of 70-2,990 ppm. Total count and mesospore removal were likewise consistent.

WASHING

The initial washing of raw product is primarily to remove dust and dirt adhering to the product. These become mixed in the water as settleable or suspended solids and can be transported from the operation only in water. However, other extraneous materials (such as leaves and vines) often accumulate as floating debris in wash tanks and flumes. These waste materials should be skimmed from the water, either manually or by mesh belt or other skimming devices, and deposited into large containers. Preventing these materials from entering the gutter system will minimize the volume of water required to transport wastes generated at this operation.

Intermediate and final washing of prepared product are normally provided to remove fragments and unwanted components (such as peel and seeds) from the primary product flow. The materials removed in such operations are frequently transported in the washwater generated at these points. However, when the water from these operations is recovered for reuse, removal of these materials from the water is desirable. Screens may be used for this purpose. When solid materials are so separated, dry handling procedures should be provided thereafter. Containers are generally suitable since only small quantities of solid wastes are removed; mechanical or pneumatic conveyors may also be used. Use of dry handling procedures eliminates the need for water and prevents contributions to the organic load which may result from further leaching of soluble matter.

Sorting (Inspecting), Trimming

Sorting and trimming operations involve manual removal of unusable materials from the product flow. In the sorting operation (sometimes referred to as inspecting or picking), cull and other unusable whole units are removed. In the trimming operation, only blemished, bruised or overripe segments are manually cut from whole units.

Solid residuals from both operations will contribute significantly to the organic load if placed in water. Therefore, these materials should be handled dry. When belt conveyors are used to convey the raw products as they are being inspected, the lower return belt is frequently used to transport the rejected materials or trimmings away from the processing area. Alternatively, these materials may be manually placed into hoppers of a pneumatic conveying system or into containers such as pans, boxes or barrels.

When the product being inspected consists of relatively small particles (such as peas, cut corn and diced produce), specially-designed pneumatic equipment is available to assist in removing unusable material. This equipment is similar to a hose and nozzle of a home vacuum cleaner. The system will transport removed materials to an outside storage facility.

PEELING

Several types of equipment are used to peel a variety of fruits and vegetables. The peelers are classified as: (1) steam peelers, which are used mainly for carrots and other root vegetables; (2) mechanical peelers, such as mechanical knives for fruits and abrasive peelers for root crops; (3) chemical peelers for fruits and vegetables; and (4) dry-caustic peelers to soften the skin prior to mechanical removal.

Steam and Conventional Chemical Peelers

Steam peelers produce finely divided particles of solid waste which are difficult to separate from water. The solid wastes from conventional chemical peelers, where water sprays are used to remove peel material, are also finely divided. In both of these situations, the peel material must be discharged with the liquid effluent, thereby offering no alternative by which the organic load may be reduced.

Mechanical Knife Peelers

Mechanical knife peelers, which may be equipped with coring devices, are widely used to pare apples and pears. The peel material is removed as large discrete particles; the cores as cylindrical "plugs." These materials are normally separated from the peeled fruit by the machines and can readily be collected and transported on a separate conveyor. Since these materials contain soluble organic matter which will be readily leached into water, use of hydraulic systems should be avoided. Maximum yields for by-products, especially with apples, will be realized by dry handling these materials.

Abrasive Peelers

Abrasive peelers generate a slurried waste material, the consistency of which is largely dependent upon the quantity of water used in the peeling equipment. Such slurries have extremely high BOD and suspended solids content. Elimination of these materials from discharged wastewater will result in a measurable reduction in the organic load.

The peel slurry can be collected in a hopper or a catch pan situated below the peeler. The consistency of the slurry will enable pumping of the collected materials to the waste storage area. By mxiing the peel slurry with other food residuals, the free moisture content of the blend will still enable disposition of the materials by normal means. However, the consistency of the peel material should be maintained as thick as practicable by minimizing water usage in the peelers, thereby minimizing the quantity of free mositure in the residual blend.

Dry-Caustic Peelers

The U.S. Department of Agriculture dry-caustic peeling system uses mechanical energy from rotating studded rubber rollers to abrade softened peel from the caustic treated raw product. This system was developed by the Western Regional Research Laboratory of the USDA in the late 1960's as an alternative to the hydraulic removal of peel. This system involves the removal of peel softened by treatment with hot solutions of sodium hydroxide with high pressure water sprays.

The commercial application of dry-caustic peeling has been primarily for root crops, but recently it has been used for non-root crops such as peaches. It has been used most extensively for white potatoes and less for red beets, sweet potatoes and carrots. Table IV-20 summarizes the reported installations of dry-caustic peelers for root crops up to midyear 1974.

Table IV-20.– *Commercial dry-caustic peeling of root crops in 1974*[38]

Commodity	No. of units	Total production, ton/hr.
White potatoes	121	1,100
Sweet potatoes	5	40
Red beets	11	67
Carrots	8	55

Example 1–Peeling of Table Beets

Lee *et al*[39] presented results of experiments that adapted the dry-caustic process for peeling beets. The major source of pollution load in the processing of beets is the peeling operation. The waste effluent generated from conventional peeling is highly alkaline and contains considerable amounts of dissolved organic matter. This waste represents approximately 50% of the total plant effluent and more than 90% of the total plant solid waste.

In the conventional peeling operation of a typical beet processing plant, solid and liquid waste generated from the peeling line pass through a 20-mesh screen to remove the gross solids. Then the liquid is pumped to a lagoon or delivered to a waste disposal system. The gross solids are usually removed to a landfill. However, the very fine organic particles pass through the screen and contribute to the major wastewater BOD and COD.

A pilot plant dry-caustic unit at the New York State Agricultural Experimental Station was compared to a commercial scale peeler installed at a local processing plant. The results of these two peeling operations are shown in table IV-21.

In processing 80 tons of fresh beets per day, the volume of water used in conventional peeling in both the tumble peeler and the abrasive peeler is around 48,000 gallons per day. When the tumble peeler is replaced with a scrubber, the water consumption volume is reduced to 12,000 gallons per day (75% reduction). Convention peeling generates 10,200 lbs. of total solids, while

Table IV-21.—*Water usage and properties of effluent waste flow in two different peeling operations of beets*

Measurement[a]	Conventional peeling	Dry caustic peeling
Raw beets input, ton/day	80	80
Water flow rate on peeling line, gal/day	48,000	12,000
Total solids, lb/day	10,200	1,050
Suspended solids, lb/day	340	40
COD, lb/day	6,500	390
BOD, lb/day	2,670	190

[a] Average of 4 composite samples.

dry-caustic peeling produces only 1,050 lbs. of total solids. Therefore, more than 85% of the total solid waste is collected and segregated from the main plant effluent. Suspended solids were reduced from 340 lbs. to 40 lbs. per day by the dry-caustic peeling operation. The dry-caustic peeling operation affected more than 90 percent reduction in both COD and BOD.

Example 2—Cling Peach Peeling

The dry-caustic process was also applied to cling peach halves with a mechanical peel removal system during the 1972 season at Del Monte, San Jose, California. The soft fruit (and tomato) peel removal units consist of a manifold of rotating rubber discs which convey the fruit and wipe off softened peel simultaneously. The initial demonstration of the cling peach peelers was in a commercial cannery[40] with the first commercial utilization of dry-caustic peeling of cling peach halves in 1971.[41] This first commercial installation was operated during the 1971-1973 processing seasons.

Figure IV-20 is a schematic of a commercial mechanical peel removal unit having a capacity of 12 to 15 tons/hour of cling peach halves.

Table IV-22 summarizes overall results of commercial dry-caustic peeling of cling peaches and compares the conventional (hydraulic) system with the dry-caustic (mechanical) system for peel removal. The water use is reduced 90% and the BOD generation is reduced 50-60% when the dry-caustic system replaces the hydraulic system. The reduced cost of liquid waste treatment resulting from use of dry-caustic peeling is partially offset by the cost of disposal of peeling sludge (approximately 50 lb./ton of raw peaches peeled). The peeling sludge from dry-caustic peeling of peaches has been disposed of by sanitary land fill or by land spreading and cover. In the future, if all cling peaches canned in California were dry-caustic peeled, the estimated 17,000 tons of sludge produced would probably be utilized as an animal feed component.[41] The number of commercial dry-caustic peeling units currently used in peach canning is five with a total production of 70 tons per hour.

Example 3—Peeling of Tomatoes

Hart *et al*[42] described results obtained from a pilot scale study (2 to 4 tons per hour) using rotating rubber discs to remove the peel from caustic treated tomatoes. Figure IV-21 is a schematic drawing of the pilot system.

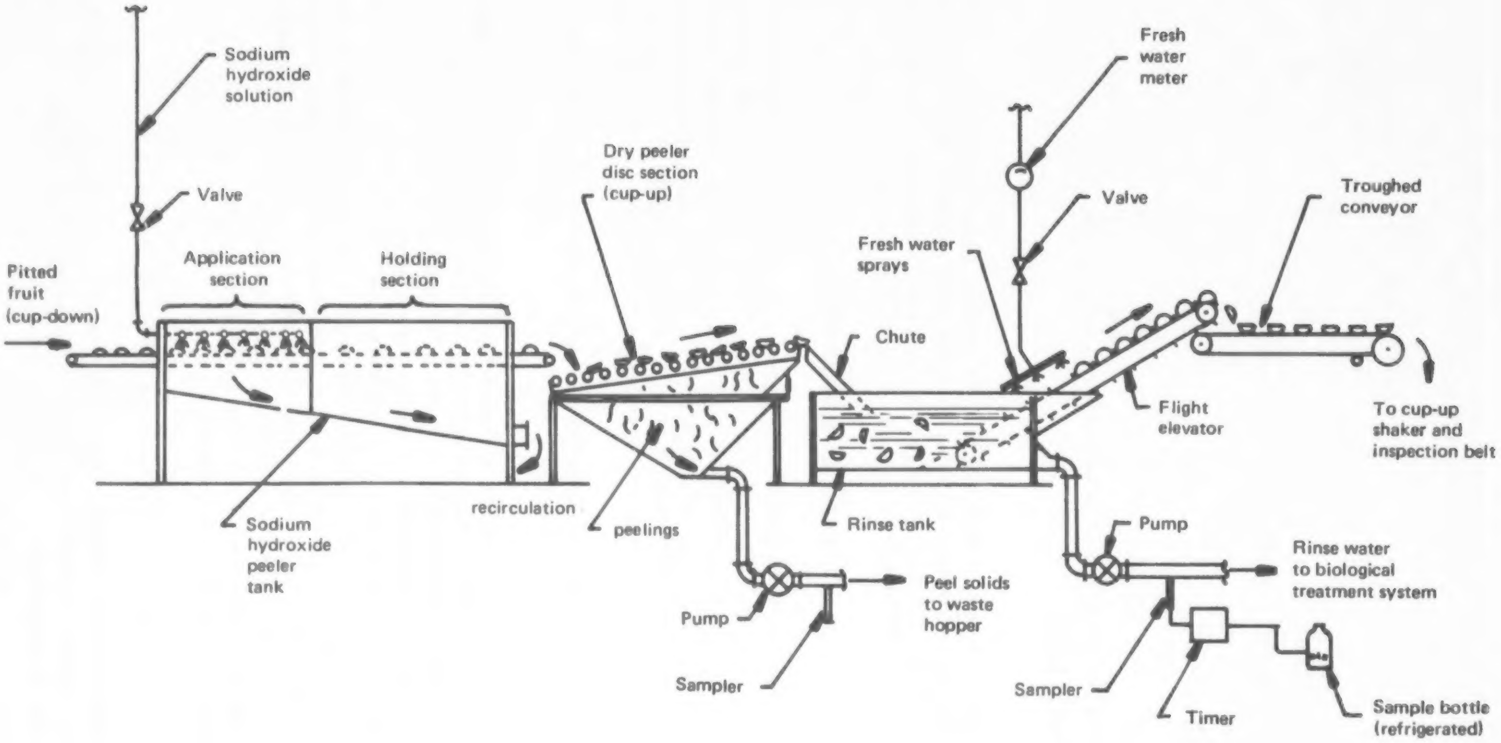

Sodium hydroxide solution
Valve
Pitted fruit (cup-down)
Application section
Holding section
Sodium hydroxide peeler tank
recirculation
Dry peeler disc section (cup-up)
peelings
Pump
Sampler
Peel solids to waste hopper
Chute
Rinse tank
Fresh water sprays
Fresh water meter
Valve
Flight elevator
Troughed conveyor
To cup-up shaker and inspection belt
Pump
Rinse water to biological treatment system
Sampler
Timer
Sample bottle (refrigerated)

Figure IV-20. Schematic of dry-caustic peeler.

Table IV-22.—*Hydraulic versus mechanical peel removal for cling peaches*[41]

[per ton of raw peaches] [a]

	Hydraulic	Mechanical
Water use, gallons	850	90
BOD, pounds	6.7	2.7
SS, pounds	5.1	1.9
Peeling loss, %	6.45	7.35

[a] Data from 1971 season which was confirmed in the 1972 and 1973 seasons.

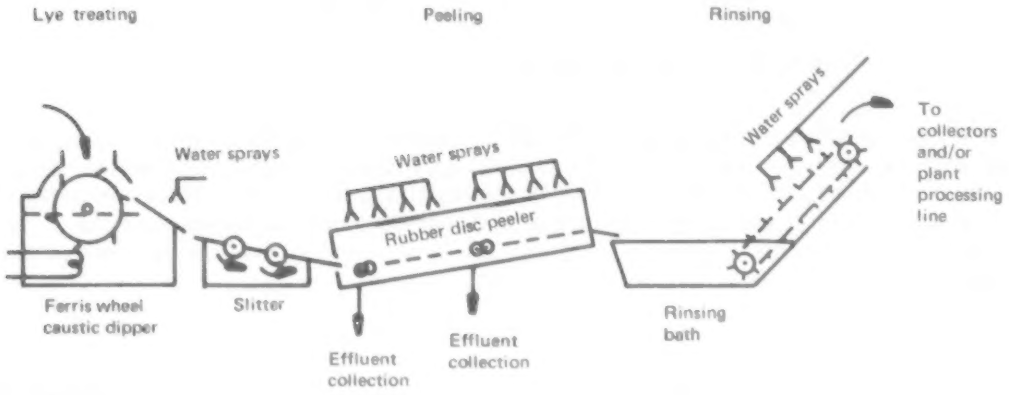

Lye treating
Peeling
Rinsing
Water sprays
Water sprays
Water sprays
Rubber disc peeler
To collectors and/or plant processing line
Ferris wheel caustic dipper
Slitter
Effluent collection
Effluent collection
Rinsing bath

Figure IV-21. Pilot scale peeling line.

Tomatoes were normally immersed in the caustic dipper (18% caustic) at 220°F for 30 seconds. Following this, the skins were slit by passing the tomatoes over a series of rotating blades that extended about 0.10 inches above the surface. The peeler consisted of a series of shafts housing flexible rotating rubber discs. The speed of rotation was 300 to 400 rpm. Above the disc bed were a number of sprays to wash and aid in removing caustic from the tomatoes. After the disc peeler, tomatoes were given an additional wash and rinse.

The volume of fresh water used for peeling varied with the feed rate but averaged 74 gallons per ton of sorted tomatoes when the peeler was being operated at, or near, capacity (table IV-23). This is a substantial reduction compared to the usual 300 to 500 gallons per ton for conventional lye peeling.

Most runs generated only 70-80 gallons of effluent per ton of sorted tomatoes because of the low volume of fresh water. The effluent carried approximately 18 pounds (dry weight) and the screenings 5-6 pounds (dry weight) of solids per ton of sorted tomatoes. The low volume and relatively high concentration of effluent enabled it to be handled more efficiently by conventional treatment. Thus, the process should show savings in both water and treatment costs.

Table IV-23.–*Average water usage and peeler effluent characteristics*[a]

Water usage	74 gal/ton
Effluent	
Volume	74 gal/ton
Concentration	2.9% total solids
COD	17.5 lb/ton
Total solids	17.6 lb/ton
Total volatile solids	10.0 lb/ton
Suspended solids	2.5 lb/ton
Volatile suspended solids	2.2 lb/ton
pH	11.9
Screenings	
Total solids	5.1 lb/ton
Wet weight	33.9 lb/ton

[a] Based on feed weight of sorted tomatoes

The relatively high concentration of the effluent presents a possible alternative to the usual sewage disposal. At an average concentration of about 3% solids, it may be economically feasible for a canner to concentrate the effluent, recover the water and then dispose of the concentrated waste. Concentration might be done by settling and centrifuging of the suspended solids or by evaporation. In either case, the recovery costs would then be balanced against the conventional disposal costs in order to determine feasibility of this procedure.

Example 4–Infrared Dry-Caustic Process[43]

The infrared dry-caustic peeling process for potatoes involves several steps. Wet-washed potatoes are immersed in a hot dilute lye solution. The excess lye is drained and the potatoes stand for about 5 minutes to allow the caustic to penetrate. Following the holding period, the potatoes are subjected to infrared heat for 1 or 2 minutes. The infrared heat activates the caustic and dries the surface layer of the potato. After conditioning by the heat, the potatoes are placed in a rubber-tipped mechanical peeler which removes the treated outer surface of the potato. Finally the potatoes are brush washed to remove a very small amount of soft sticky residue from their surfaces.

The gas-fired infrared heaters are of the type commonly used for space heating. Combustion takes place just in front of a ceramic mantle which radiates at 860° to 890°C (1550° to 1600°F). A nichrome wire screen protects the mantle from contact with the potatoes.

Peeling losses are about 8 to 10% with fresh potatoes of regular shape and few blemishes. They run up to 20% and over with old potatoes that have many blemishes. All potatoes could be peeled satisfactorily. The risk of producing a partially cooked translucent superficial layer ("heat ring") can be avoided provided the lye treatment is not preceded by any heating and the mechanical peeling takes place immediately after the infrared irradiation.

Part of the peel is abraded off during the irradiation and dries as a result of the heating, but without charring. About one half of the peel solids are thereby removed. This residue has a sodium hydroxide content of about 3% with 30% ashes, 9/10 of which are sodium carbonate. It can be burned, buried for land disposal, or wetted to 35-40% solids, submitted to bacterial action so as to lower its pH, and mixed with animal feeds. The residual peel material from the peeler has a solids content of 23-28%, a sodium hydroxide content of about 13%, and an ash content of 18% on a dry basis.

The potatoes leaving the peeler have a small amount (about 0.5%) of soft semisticky tissue which is readily removed with a small amount of water. The potatoes were essentially free of caustic, except in deep eyes and cracks.

In light of these results, three 9-ton/hour lines were installed in 1970 in one plant.[44] In addition to a savings of about 80% in the consumption of sodium hydroxide and of a reduction of 1/3 of the peeling losses, the savings in water exceeded 95%. Moreover, there was no longer any wastewater to dispose of because the residues (solid material plus water) were collected as a thick slurry of 12-15% solids which could be fed to cattle after neutralization. However, due to increased energy costs, these units are not currently used.

Additional Dry Peel Removal Studies

A dry peel removal machine, entirely different in design and operation, has been recently tested on peaches and tomatoes. Known as a Magnuscrubber Model HC, the machine is circular in design rather than the flat bed type. The soft rubber discs are assembled in a circular revolving cage with a feed screw through the center. The feed rate is controlled by this central screw conveyor. The product flow is parallel to the roll axis and perpendicular to the surfaces of the discs. On a flat bed machine, the orientation of the product is just the opposite.

In one study, surveys were made at three peach and tomato processing plants.[5] This study concentrated on determining the reductions obtained by this new dry scrubber for the peel removal operation and the impact of this on the total plant effluent. Data presented in tables IV-24 through IV-27 have been extracted from the study report.

Table IV-24.–*Caustic peeling of peaches – reduction of peeling wastes with Magnuscrubber*

Parameter	Peel removal method		Reduction with Magnuscrubber
	Spray washer	Magnuscrubber	
	(Per 1000 lbs. of canned peaches)		
Water flow	694 gals.	13 gals.	98%
BOD	8.6 lbs.	0.3 lbs.	97%
COD	12.6 lbs.	0.9 lbs.	93%
Suspended Solids	2.3 lbs.	0.2 lbs.	91%

Table IV-25.–*Peach canning – reduction of total plant wastes with Magnuscrubber*

For total plant	Peel removal method		Reduction with Magnuscrubber
	Spray washer	Magnuscrubber	
	(Per 1000 lbs. of canned peaches)		
Water	1470 gals.	789 gals.	46%
BOD	13.6 lbs.	5.3 lbs.	61%
COD	25.2 lbs.	13.5 lbs.	46%
Suspended Solids	6.5 lbs.	4.4 lbs.	32%

Table IV-26.—*Caustic peeling of tomatoes – reduction of peeling wastes with Magnuscrubber*

Parameter	Peeling removal method		Reduction with Magnuscrubber
	Water washing	Magnuscrubber	
	(Per 1000 lbs. of canned tomatoes)		
Water flow	604 gals.	14.5 gals.	98%
BOD	6.0 lbs	2.4 lbs.	60%
COD	10.2 lbs.	3.1 lbs.	70%
Suspended Solids	2.2 lbs.	0.5 lbs.	77%

Table IV-27.—*Tomato canning – reduction of total plant wastes with Magnuscrubber*

For total plant	Peel removal method		Reduction with Magnuscrubber
	Water washing	Magnuscrubber	
	(Per 1000 lbs. of canned tomatoes)		
Water flow	3750 gals.	2690 gals.	28%
BOD	49.3 lbs.	31.4 lbs.	36%
COD	93.2 lbs.	44.5 lbs.	52%
Suspended Solids	45.3 lbs.	–	–
pH of water waste	9.4	6.2	–

In another study completed in 1975, a Magnuscrubber was evaluated over an entire cling peach season.[7] Particular attention was devoted to development of data on yield losses. Some of the findings of that study are as follows:

- Caustic concentration

Water peel:	2.0 - 2.7%, average 2.4%
Dry peel:	1.5 - 2.3%, average 1.8%
Savings:	25% less caustic with dry peel

- Yield loss

Water peel:	7.1%
Dry peel:	6.1%
Savings:	1% increase in product yield

There was some limited data to indicate the dry peel process left less skin on the peaches than the conventional system. The appearance of the peaches was better with the dry peel process than with the conventional process.

BLANCHING

Vegetables which are preserved for long-term storage by freezing, dehydration, or canning receive a treatment (known as blanching) with hot water or steam. The purpose of blanching is to deactivate enzymes and to remove tissue gases. In addition, blanching frequently accomplishes or facilitates removal of juice, soil, insects and other debris from the vegetable pieces.

Present methods for the blanching of vegetables prior to freezing, dehydration or canning use large volumes of water or steam, resulting in effluents heavily loaded with organic material which constitute a major source of pollution. The National Canners Association has estimated that if waste strength were reduced by 50% for the seven major processed vegetables (peas, corn, tomatoes, green beans, spinach, white potatoes, carrots), the suspended solids in wastewaters from plants could be reduced by 40 million pounds (20,000 tons), and the BOD by 70 million pounds (35,000 tons). Conventional blanching has also the disadvantage of extracting nutrients, mineral salts, water soluble vitamins, and sugars.

Steam blanching will partially avoid these difficulties; however, in order to obtain the needed capacities, the products are distributed in thick layers on the belts conveying them through the blanching tunnels, and submitted to long exposures to steam so as to inactivate the enzymes in the center of the largest pieces deepest in the beds. Surface sloughing and non-uniform texture may result.

Two-Step Quick Blanching (Individual Quick Blanch)

In the blanching process developed by the Western Regional Research Laboratory,[45] blanching is carried out in two steps. In the first step, the product is spread in a thin layer and is rapidly brought to the desired temperature. In the second step, the product is discharged as a deep bed onto another conveying belt moving slowly through an insulated chamber, so as to let the temperature equilibrate in each piece and act upon the enzymes for a time sufficient to inactivate them. Figure IV-22 shows schematically how this process called Individual Quick Blanching (IQB) is carried out.

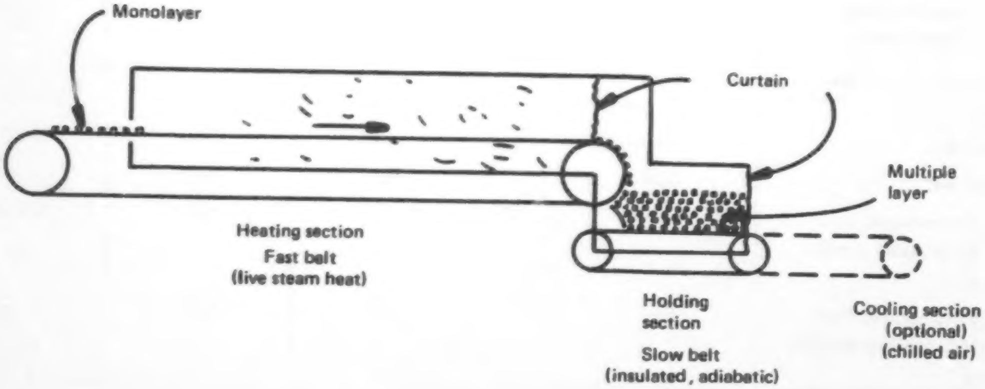


Figure IV-22. Individual quick blanching unit.

For 3/8-inch dices of carrots, 25 seconds in the steam at 100°C, followed by a holding time of 50 seconds, are adequate to give a peroxidase inactivation equivalent to that obtained by conventional blanching.

Lund[46] reported on the application of IQB to vegetables prior to canning. In that study, peas, corn, lima beans and green beans were blanched by: (1) the IQB process, (2) the IQB process with predrying, and (3) pipe blanching. Compared to pipe blanching, the IQB process reduced wastewater generation by up to 99%. The study also revealed that although predrying to greater than a 6% weight reduction would further reduce wastewater generation, product quality was adversely affected.

Concerning the volume of effluent, its solid load and the yield of the product, the experiments that were carried out compared conventional steam blanching (about 4 pounds/sq. ft. of conveying belt) to the new method (1 pound/sq. ft.). Effluent volume can be decreased by not wetting the surface of carrot dices, and even by drying it slightly, before the exposure to steam (see table IV-28).

Superficial drying is obtained by submitting the diced carrots to warm (150°F-66°C) air for 5 to 8 minutes. Table IV-28 shows that by simply not wetting the diced carrots, the effluent is already appreciably reduced. The reduction reaches almost 95% when the new blanching process is applied to diced carrots pre-conditioned so as to evaporate surface moisture.

The equilibration of the temperature of the carrot dices after the heating phase has been the object of a mathematical study.[46] The solution of the differential equation which has been developed allows us to calculate the temperature gradients as a function of time inside a cube of carrot and to establish the conditions for perodidase inactivation. The mathematical calculations have been confirmed experimentally, and present a wider interest in that they apply to all reactions in which the temperature acts according to Arrhenius' equation.

The blanching process just described is more appropriate prior to freezing or dehydration than to canning, in which blanching performs other functions than merely enzyme inactivation.

Table IV-28.—*Effect of pre-conditioning treatments on blancher effluent and product yield for 3/8 inch carrot cubes*

Pre-conditioning treatment	Blanching method	Effluent volume total flow	Effluent total solids %	Product yield %
Wet	Conventional	15.3	–	103.4
Not wet	Conventional	11.1	5.4	102.1
Not wet	IQB	6.6	4.2	106.2
Pre-evaporated to a 5.8% product weight loss	IQB	2.8	5.8	102.2
Pre-evaporated to a 10.5% product weight loss	IQB	0.8	5.3	99.8

Hot Gas Blanching

Comprehensive surveys of waste generation in food canning operations made by NCA have established blanching as a major source of strong liquid wastes in vegetable preservation.[8] Commercial blanching with hot water is a primary source of BOD in the processing of many vegetables. Steam blanching produces much lower wastewater volumes. A highly desirable replacement system for vegetable blanching would produce little or no wastewater. Microwave blanching is effective for many vegetables and produces small wastewater volumes. However, it requires large volumes of water to the cooling equipment. This, together with the high equipment costs and large energy requirement for microwave blanching, makes it economically unattractive for a seasonal vegetable processing operation.

During the period of 1971 to 1973, the Western Research Laboratory of NCA explored the use of hot gases to blanch vegetables. The concept of treating vegetables (to deactivate enzymes and expel cellular oxygen) using the heat content of combusted hydrocarbons directly was tested in a prototype unit with a design capacity of 500 lb/hr. The experimental hot gas blancher was an insulated box containing a 125,000 BTU/hr. natural gas furnace at one end. The furnace had an external air supply turbine. Combustion gases were circulated with a blower. Steam was injected through a single opening in the blower inlet duct to increase heat exchange rates and to minimize dehydration losses from the high water content vegetables. The vegetables were conveyed through the heated zone on a wire mesh belt. Schematic drawings of the hot gas blancher have been published.[47] [48] The installation of the hot gas blancher included electrical, gas, and steam flowmeters to develop information on operational costs of commercial size units. Recent work with the hot gas blancher involved in-plant studies using commercially prepared vegetables for blanching.[49] Numerous short duration experiments were conducted to establish good operating conditions and to demonstrate that hot gas blanched material could be returned to production with no loss in final product quality. The loading rates and operational conditions for in-plant hot gas blanching of vegetables are summarized in table IV-29.

The data in table IV-29 illustrate the light loading, long residence time, and high steam requirements for corn-on-cob and beets, due to their large size and slow rate of heat penetration. The corn-on-cob was preserved by freezing and it was necessary to blanch until all enzyme activity in the cob was destroyed. The use of hot gas blanching for large-piece-size vegetables does not look promising at the present time due to equipment and operational costs. The most promising commodity for hot gas blanching is cut green beans. It was possible to use heavy loading, short residence times and low steam injection to achieve the partial enzyme deactivation necessary to avoid skin separation (sloughing) in the final canned product. Hot gas blanching appears to hold promise for smaller-piece-size or thin vegetables due to the high potential for almost complete elimination of wastewater generation.

Table IV-29.—*In-plant hot gas blanching of vegetables*[49]

Commodity	Loading lb/hr.	Residence time min.	Temp. °F	Steam lb/min.
Green beans	1,580	1.3	185	0.63
Corn-on-cob	240	14	220	6.3
Beets	245	25	245	4.2
Spinach	320	1.8	225	0.5
Green peas	610	3.5	230	2.2

Table IV-30 demonstrates the percentage reductions in wastewater volume, weight of BOD, and weight of suspended solids which result when hot gas blanching replaces steam or hot water blanching.

Table IV-30.–*Reductions due to use of hot gas blanching of vegetables* [49]

Commodity	Wastewater volume	BOD	SS
Green beans	99.9	99.9	99.9
Corn-on-cob	33.3	28.8	18.7
Red beets	(2.2)[a]	47.5	37.0
Spinach	99.9	99.8	99.5
Green beans	94.2	91.4	93.0

[a] Increase in wastewater volume.

Quality examination of final products from hot gas blanching of vegetables has shown no significant difference from commercially blanched (steam or hot water) samples. With a few isolated exceptions, the retention of vitamins and minerals is similar for commercially blanched and hot gas blanched vegetables. No significant difference in trace levels of polynuclear aromatic hydrocarbons could be found in samples of hot water and hot gas blanched cut green beans. Thousands of cases of canned products containing hot gas blanched vegetables have been sold with no adverse consumer reaction.

Several equipment supply companies have working drawings of hot gas blanchers prepared for potential customers. To date, no commercial size hot gas blancher has been constructed. Deterrents to commercial utilization of hot gas blanching of vegetables are the high estimated equipment costs and the uncertain supply of natural gas or propane in future years. The hot gas blancher is more complex than a hot water blancher due to burners, blowers, gas and mandatory safety devices. The trade-off of the higher cost of a hot gas blancher against the lower cost for water and waste disposal will need to be estimated for each potential application of hot gas blanching. Fossil fuel energy sources will be in short supply for the period of 1974-1980. The reasons for the potential shortage of such fossil fuels as natural gas are the high growth rate of energy consumption (4% per year) and reduction in the U.S. reserves-to-production ratio. The predicted shortage of natural gas may cause potential users of hot gas blanching to postpone use of this new system. Fortunately, the hot gas blancher can be operated with liquified propane as a fuel. Under the allocation program in effect since May 1974, food processing is one of the categories listed as priority customers (some others are residential uses, agricultural production and mass transit vehicles). Therefore, it is likely that vegetable processors using hot gas blanching could get adequate supplies of propane.

Vibratory Blanching and Cooling

Bomben *et al*[50] conducted a study to design, construct and demonstrate a steam blanching system capable of processing 1 ton/hour of vegetables in which the effluent was to be used as a fog spray for cooling blanched vegetables prior to freezing. This study incorporated the Individual Quick Blanching (IQB) principle with a vibratory cooling system. Figure IV-23 shows a schematic of the resultant vibratory blancher cooling system.

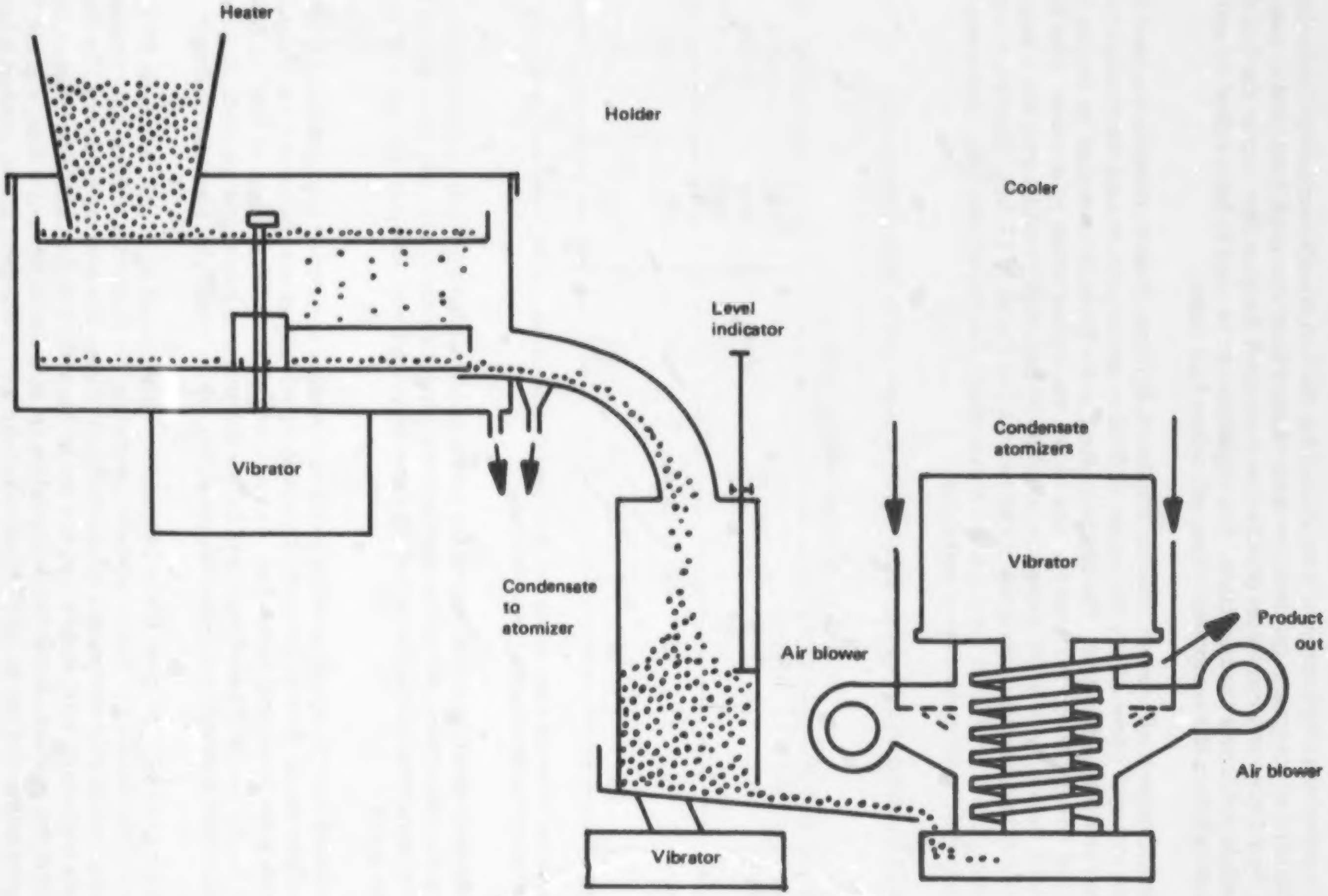

Heater
Holder
Cooler
Level indicator
Condensate atomizers
Vibrator
Vibrator
Condensate to atomizer
Product out
Air blower
Air blower
Vibrator

Figure IV-23. Schematic diagram of vibratory blancher cooler.

Solid surface vibrating conveyors were chosen for the heat transfer surfaces in the heater and cooler. This type of equipment can be more easily cleaned than wire mesh belts used in most steam blanchers. Spiral vibratory conveyors provide a very compact design as they can be stacked close together and do not have a return section. The vegetables can be used to form a product seal at the entrance and exit from the equipment which will reduce heat losses.

An electromagnetically-driven, variable amplitude, Syntron circular conveyor was used in the heater. The conveyor operated at a frequency of 3600 cycles/minute, causing the product to move in an upward and forward motion. The residence time in the heater is controlled by varying the feed point and the amplitude of vibration. The cooler was a spiral vibratory elevator. Like the heater, it has a frequency of 3600 cycles/minute. The 36-inch high elevator (with five 4-inch wide flights of 14-5/8 inch diameter) gives the cooler an effective length of 17 feet. Blowers, connected to the plenum, delivered air over the product concurrently. Condensate from the heater was atomized into the cooler at the blower entrances.

Table IV-31 summarizes typical operating conditions used in these experiments.

Table IV-31.–*Typical operating conditions*[50]

Commodity	Heating time (sec)	Holding time (sec)	Feed rate (lbs/hr)	Excess steam[a] (%)	Cooling time (sec)	Cooler product Temp. (°F)
Green beans	45	45	190	12	45	100
Carrots	25	60	145	24	60	105

[a] Equals percent over theoretical steam consumption. Theoretical steam consumption for 60°F initial temperature and a 195°F final mass average temperature is 13.8 lb/100 lb feed.

The vibratory spiral conveyor used in the cooler conveyed both the carrots and the green beans uniformly and continuously. When the conveyor was tried with cut cauliflower and broccoli spears, the 4-inch conveyor was too narrow to convey these vegetables well, but they did move up the length of the spiral.

It was found that the spiral conveyor required a product velocity of approximately 17 feet/min. to give a uniform steady flow of product. This product velocity gave a residence time of only 1 minute with green beans and carrot dice. The resulting product temperature of 100° to 105°F is higher than the 70° to 80°F usually achieved before freezing in a commercial process. A conveyor twice as long would provide a 2-minute residence time, which would give adequate cooling.[51]

The lower gross yield of green beans for combined blanch-cooling as shown in table IV-32 is characteristic of air cooling.[51] The condensate sprayed on the product is only partially reabsorbed, and it does not completely compensate for evaporation of moisture into the air stream. In flume cooling, there is no evaporative weight loss, but the higher yield is accompanied by twice as much solids lost from the product. Since frozen vegetables are sold on the basis of weight, a lower yield means less production and can be justified economically only if the value of lost product is balanced by the cost of increased waste disposal and increased quality of the final product.

Table IV-32.—*Comparison of yields and solids loss in effluent for green beans between combined blanching and cooling vs conventional blanching and flume cooling*[51]

Process	Gross yield[a] (%)	Effluent solids loss[b] (%)	Reference
Combined vibratory blanch-cool	88	2.6	This work (51)
Conventional steam blanch flume cool	95	5.7	(8)
Conventional water blanch flume cool	96	6.1	(8)

[a] $\text{Gross yield} = \frac{\text{Wt. of cooled product}}{\text{Wt. of feed to blancher}}$

[b] $\text{Effluent solids loss} = \frac{\text{\% solids in effluent} \times \text{wt. of effluent}}{\text{\% solids in feed} \times \text{wt. of feed}}$

The results in table IV-33 show the large difference in volume of effluent between conventional processing and the combined blanch-cooling.[51] Most of this volume (96%) is due to the flume cooling. Assuming a product temperature out of the blancher of 195°F and cooling water temperature of 60°F, it requires 5.8 lb. of water per lb. of product to obtain an 80°F product temperature. This amount of flume water when added to the blancher effluent results in twice the amount of COD and 70 times the volume of effluent from combined blanching and cooling.

Table IV-33.—*Comparison of effluent from green beans for combined blanching and cooling and conventional blanching and flume cooling*[51]

Process	Effluent (lb/100 lb feed)	COD (lb/100 lb feed)	Reference
Combined vibratory blanch-cool	7.0	0.17	This work (51)
Conventional steam blanch flume cooling	500	0.35	(8)
Conventional water blanch flume cooling	520	0.32	(8)

If no change is made in the way frozen vegetables are marketed, then air cooling of any kind suffers a large cost disadvantage. Table IV-34 gives a comparison of the approximate operating costs of three different kinds of blanching. The basis for this cost estimate is taken from Brown *et al.*[51] It must be emphasized that these costs are approximate, and they are shown merely to make a comparison. It is obvious that the cost of lost green beans (at $0.20/lb) due to reduced yield is overwhelming in comparison to other costs. Even though the combined vibratory blanch-cooler can give substantial savings in steam and effluent costs, and a product with more retained solids, these will not balance the cost of product lost through evaporation.

Table IV-34.–*Comparison of operating parameters for the blanching and cooling of green beans*[51]

Water and effluent	Combined vibratory blanch-cool	Conventional steam blanch-flume cool	Conventional water blanch-flume cool
gals/ton	140	1200	1250
$/ton	0.06	0.48	0.50
lb/ton	3	7	6.4
$/ton	0.06	0.14	0.13
Electricity ($/ton)	0.06	0.007	0.007
Steam ($/ton)	0.31	0.55	0.8
Product loss ($/ton)[a]	28	0	0
Total cost ($/ton)	28.43	1.17	1.43

[a] Frozen green beans at $0.20/lb.

Design of Large Scale Vibratory Blanch-Cooler

To evaluate fully the technical feasibility of the combined blanch-cooling approach to processing frozen vegetables, it is necessary to work with larger scale equipment. Figure IV-24 is a schematic diagram showing the configuration and the dimensions of a 1 ton/hr. vibratory blanch-cooler. The heater and cooler would have adjustable feed points to accommodate the different residence times needed for different products. The holder would be a live bottom bin with an automatic level control, which could be adjusted to maintain different holder residence times. The cooler would use the same type of conveyor as in the heater, but the central column of the spiral could be used to direct the air flow. The cooler spiral conveyor would have to be much longer to accommodate up to 5-minute residence time for large vegetables such as broccoli and Brussels sprouts.

Blancher modifications are still in the research and development stage. All of the studies discussed were supported, in part, by grants from the Environmental Protection Agency. As indicated in the discussions, some look promising while others have problems. There is still a need to develop these and other approaches towards solving blancher effluent problems and to evaluate the most promising methods on a commercial scale.

CUTTING, SLICING, DICING

Many products are cut or otherwise reduced in size by highly automated equipment. For example, green beans are snipped, cut or sliced; fruits are sliced or diced; and root vegetables are sliced into several styles or diced. Each of these operations produces undesirable fragments of product which are normally separated from the desired material. The small bits and pieces are most frequently removed by rotating or vibrating screens, often with the aid of water. The high percentage of exposed surface of inner tissues in cut pieces results in rapid leaching of soluble organic matter into water. Therefore, when cut fragments are hydraulically conveyed, the resulting wastewater will contain a very high organic load. For this reason, it is highly desirable to handle such materials in containers or with mechanical or pneumatic conveyors.

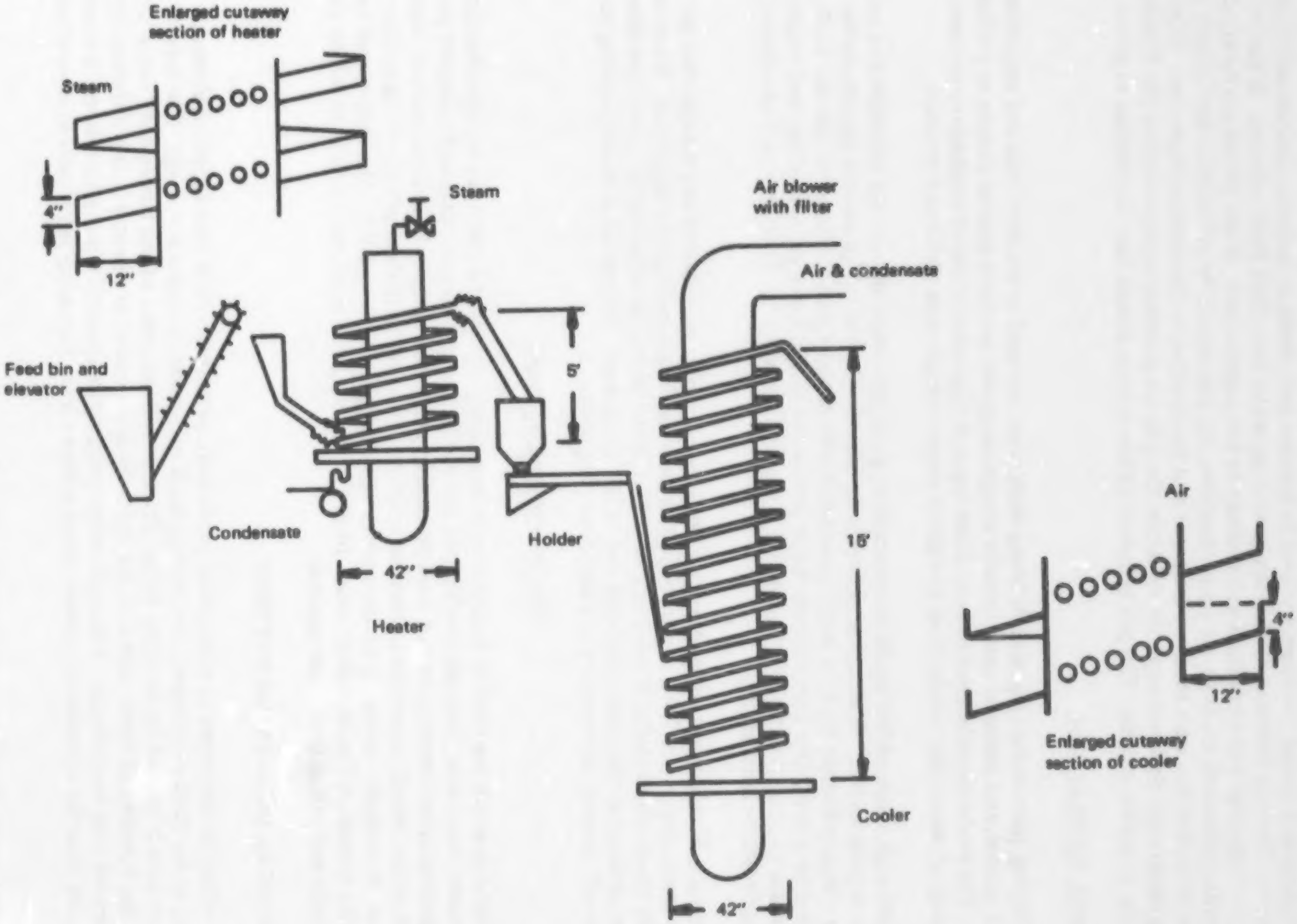

Enlarged cutaway section of heater
Steam
4"
12"
Steam
Feed bin and elevator
Condensate
42"
Heater
5'
Holder
Air blower with filter
Air & condensate
15'
Cooler
42"
Air
4"
12"
Enlarged cutaway section of cooler

Figure IV-24. One ton per hour vibratory blancher cooler.

PITTING

Automated pitting machines are used to destone such fruits as apricots, cherries, olives, peaches and plums. The pits removed by this equipment generally have fruit flesh adhering. If placed into water, this material will contribute significantly to the organic load. Some pitters separately discharge the stones and the fruit. In such situations, the pits should be collected either in large containers or, preferably, on a separate conveyor and transported to the waste storage area. When the pitting equipment does not separate materials, the pits are generally separated from the fruit by revolving or shaker screens. The pits removed by the screens should then be handled as above.

PULPING, EXTRACTING

Pulping, juice extracting, and finishing equipment are used to produce fruit and vegetable nectars, purees, and juices by mechanically compressing raw products against screens or perforated plates. The waste material ejected from these types of apparatus is called roughage or pomace, consisting of stems, skin, seeds, fiber and other coarse components of the raw product.

Although much of the liquid is extracted by these processes, the ejected materials still contain soluble organic matter. When these materials are placed into water, the soluble organic matter creates a high pollution load. A study conducted with tomato pomace revealed that the BOD load generated by placing this material into water was equivalent to three percent of the wet weight of the pomace (3 pounds of BOD for each 100 pounds of pomace).[52] Therefore, it is mandatory that these materials be handled dry.

Pomace from pulpers, extractors and finishers can easily be collected and transported on belt, drag or screw conveyors. Pneumatic conveyors have also been successfully employed. When the quantity of ejected material is relatively small, the material can be collected in bins or portable hoppers situated at the waste discharge end of the equipment. Any of these waste handling procedures will prevent the creation of a significant organic load.

PRODUCT CONVEYING

Methods which are used to transport raw commodity within the plant can be classified into four general categories: manual, mechanical, hydraulic, and pneumatic. Except for limited situations, technological development of food processing plants has eliminated in-plant manual handling from all except visual inspection operations whereby culls and blemished pieces of commodity are removed. Pneumatic conveying systems are relatively recent developments. Mechanical and hydraulic conveying systems are most widely used. In the following discussions, emphasis is placed on reducing waste loads emanating from these systems.

MECHANICAL CONVEYING SYSTEMS

Mechanical conveyors in widespread use include belts (both solid belting and steel-mesh), vibrating or oscillating conveyors, live rollers, buckets, screws or augers and drags. The type of conveyor used is limited by the nature (dry, fluid, whole, cut, etc.) of the commodity being handled. Hence, the quantity of water used and the waste loads generated in relation to the different types of conveyors vary accordingly.. Although water usage by mechanical conveying systems is normally minor, care must be exercised to prevent these systems from becoming significant sources of waste loads.

Screw conveyors are most frequently used to transport dry materials such as flour and granulated sugar, or solid waste materials. In either situation, buildup of bacterial populations is not of urgent concern. Water usage is generally limited to cleanup operations. Drag conveyors are used most frequently to transport whole product from delivery areas into the plant or to transport solid residuals away from the processing areas. Again, water usage is generally limited to periodic cleanup. In these situations, waste loads can be minimized by using high pressure-low volume cleaning equipment.

Belts, vibrating or oscillating conveyors, live rollers, or bucket conveyors are used at numerous points within all plants. Since these are used to transport raw product in various stages of preparation, sanitary considerations are of primary concern. To maintain an acceptable degree of equipment sanitation, water is generally applied continuously. As in the case of raw product washing, the degree of cleanliness is determined more by how water is used rather than by the quantity of water that is used. Continuous cleaning of conveying equipment is normally accomplished with sprays. Maximum efficiencies can be obtained by using high pressure-low volume spray nozzles and water which has been chlorinated to 5 ppm. Since a continuous application of water is not generally required to maintain acceptable sanitary conditions, the quantity of water used can be significantly reduced by intermittent use of the cleaning sprays. Cleaning cycles can be controlled manually or by use of appropriate timers and solenoid valves.

In addition to sanitation requirements, belts and oscillating conveyors may require a small volume of water for surface lubrication. Fogging nozzles, or other low volume mist sprays, can be advantageously used for this purpose. Use of chlorinated water, if practicable, will further retard bacterial growth and reduce the required frequency of cleaning.

HYDRAULIC CONVEYING SYSTEMS

In-plant handling of raw products in hydraulic systems (pump and pipe systems and flumes) is now widely practiced in fruit and vegetable processing plants. Hydraulic conveying systems offer the advantages of gentle product handling, additional washing of commodities, less space for vertical transport, and ease of maintaining equipment sanitation. The major disadvantages are the relatively large volume of water required and the significant organic load generated by these systems.

The organic load associated with water in hydraulic conveying systems results from the washing and leaching of soluble organic matter from the commodity being transported. The organic matter is leached from the commodity because of the osmotic difference between the transport medium and the product tissue. The quantity of organic matter (the organic load) is a function of the duration of immersion and the size of the particles. The longer a piece of product is in water, the more material will be leached into the water. Smaller particles provide greater exposed surface areas resulting in more rapid loss of solubles.

PNEUMATIC CONVEYING SYSTEMS

Among the many innovations in fruit and vegetable processing technology designed to curtail water pollution, pneumatic conveying systems offer a means to significantly reduce waste loads associated with the processing of several commodities. Where hydraulic conveyors have been replaced by pneumatic systems, both the hydraulic and organic loads have been markedly diminished. Pneumatic systems may be designed to convey materials by either positive or negative air pressure. Such systems offer the additional advantage of requiring very little floor space. A typical negative air system is illustrated in figure IV-25.

Although most types of solid wastes can be readily handled, pneumatic systems are currently able to satisfactorily handle only certain types of raw commodities. Limitations are imposed upon the size and density of the material to be transported, the distance, and the ability of the material to withstand rough handling without incurring physical damage. Commodities which are being successfully conveyed in pneumatic systems include peas, green beans, cut corn, lima beans, and carrots.[53] Solid wastes from numerous commodities are being handled pneumatically.

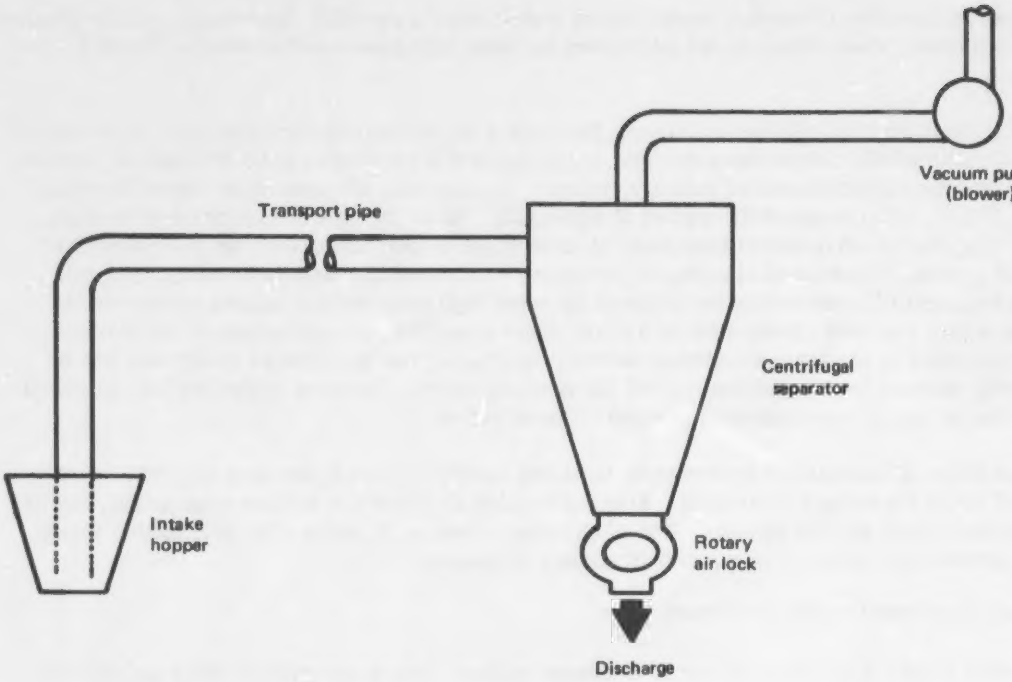


Figure IV-25. Negative air conveying system.

PLANT CLEANING

The procedures normally followed for plant cleanup consume large volumes of water. Much of the water is used simply to flush solid waste materials from equipment and floors into the gutter system. Additional quantities of water may then be required to transport the solid materials to the waste storage area. This practice not only adds to the hydraulic load of the plant effluent, but also adds to the organic load by the leaching of soluble matter from the waste materials. Wastewater loadings attributable to plant cleanup can be minimized by altering the cleanup procedure.

Prior to the use of detergents and water to clean the processing equipment and floors, food residuals should be manually placed into suitable receptacles. Materials which tend to accumulate in equipment should be brushed or scraped away. Materials on the floor should be swept and shoveled into containers. Alternatively, pneumatic conveying systems may be equipped with special attachments which can be used to vacuum clean processing areas. A dry pre-cleanup procedure is an essential part of a successful waste reduction and prevention program.

Maintenance of cleanliness in the fruit and vegetable plant may require frequent or continuous cleanup in addition to that at the end of each shift. Large volumes of water are often used to wash processing equipment, inspection tables, conveyors, walls, floors, and drains. Water is also used for cleaning areas outside the plant and for washing trucks, storage vats, produce conveyors, bins, platforms, and other equipment.

Continuous in-plant cleaning operations are conducted to keep wastes from accumulating during the operating day, thereby improving sanitation and reducing the time required for end-of-shift cleaning. In continuous cleaning, wastes may be brushed from equipment or washed away with water. The dry method is recommended whenever practicable to reduce the amount of solids carried away in water.

To maintain adequate cleanliness in the fruit and vegetable plant with minimum use of water, careful consideration must be given to the design and construction of individual pieces of equipment. Recommendations preferred by the Special Committee on Sanitation of Canning Equipment are outlined in the NCA Laboratory Manual.[54] The following discussion is limited to those procedural practices which influence the generation of waste loads attributable to plant cleaning operations.

PRELIMINARY STEPS

The contribution to the organic load by small fragments of product cannot be overestimated. As previously described, large amounts of soluble organic matter are washed or leached from the product whenever water is applied. To reduce the organic load attributable to cleanup operations, cleanup periods must be initiated by sweeping spilled material from the floors. The quantity of water then required to finish the cleanup operation will be substantially less. This is evident when one observes employees in plants where water is used exclusively during cleanup periods. So much water is expended to chase a few fragments several feet across the floor to the nearest drain!

Secondly, the use of mechanical (brushes, scrapers, squeegees) and chemical (detergents) cleaning aids, when properly used, can greatly reduce the time and increase the efficiency of cleanup operations. The quantity of water required for cleaning may be significantly reduced by using cleaning aids, especially when foods or other contaminants tenaciously stick to equipment surfaces. Cleaning aids are also discussed in detail in the NCA Laboratory Manual.

WATER HOSES

When continuous cleaning is practiced, care must be especially taken to avoid wasting water from unattended hoses. Hoses should be equipped with automatic shutoff valves to save water and to avoid spraying the rest of the plant. To maximize the effectiveness of water, valve outlets should be constructed so that nozzles of various types can be connected rapidly. The following interchangeable nozzles are suggested: a small jet type for cleaning deep cracks, a fin type for cleaning flat surfaces, a bent type for cleaning around and under equipment, and a spray head-brush combination type for cleaning surfaces where combined brushing and washing is needed.

SPECIAL CLEANING EQUIPMENT

The cleaning efficiency of water is influenced by the temperature and the pressure under which it is applied. Hot water applied under high pressure is generally most efficient, thereby requiring smaller volumes to accomplish specified tasks. Numerous cleaning devices are available whereby water can be heated, pressurized, and, if desired, mixed with cleaning chemicals at controlled rates. Such devices are available as portable units which may be used in various areas within a plant or as a stationary unit with high pressure lines piped to various outlet stations.

SAVINGS FROM EFFICIENT CLEANUP

Substantial savings can be realized by reducing cleanup labor since this constitutes the greatest part of cleanup costs. Labor reductions can most readily be achieved by reducing the time required for adequate cleaning. An added benefit will be the availability of additional time for production. However, this must be accomplished without compromising the sanitary standards which have been established for each operation.

The key to minimizing the time required for plant cleanup lies in proper design of the facility and in the use of efficient equipment and procedures. The results of installing high pressure hydraulic cleaning units and training employees in their use were documented in one plant.[55] Comparison of the labor expenditures before and after installation showed the following reductions in cleanup man-hours in a tomato cannery:

Pulper and Finisher Department	84%
Filler and Seamer Combinations	78%
Raw Fruit Belts and Related Equipment	65%
Tomato Product Bottle Lines	Over 50%
Concrete Floor Areas	40% - 60%
Holding Tanks, Catch Pans, Floor Drains, Walls, etc.	65% - 75%

Any manager would be pleased with such savings that more than justify the investment in equipment and training, and with the benefits of utilizing experienced cleanup workers. This is particularly true when the savings can be accomplished without any sacrifice of sanitation standards. Management can usually be convinced of the desirability of budgeting money for equipment, supplies and training provided reasonable estimates can be made for return on the investment.

PERSONNEL

Cleanup will only be as good as the people directly and indirectly involved. Management must be involved if cleaning of the plant is to be a success. Management has the final decisions on allocation of funds, men and materials, sets the policy for the plant and delegates the implementation to supervisors of authority.

It is the cleanup supervisor that then has the responsibility of achieving management's policy. The supervisor must have a good knowledge of cleanup equipment and materials. He should have the authority for the repair, alteration and relocation of cleanup equipment. The supervisor should have responsibility in crew selection and discipline authority. Cleanup crews put into practice what they have been trained to do. If they are well trained, well equipped and motivated, then chances are good that cleanup will be done in an efficient manner.

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APPENDIX A

LIST OF APPROVED TEST PROCEDURES

Appendix A contains reprints from:

- The Federal Register, Vol. 41, No. 232, pp. 52780-52786, Dec. 6, 1976
- The Federal Register, Vol. 42, No. 12, pp. 3306-3307, Jan. 18, 1977.

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

[FRL 630–4]

PART 136—GUIDELINES ESTABLISHING TEST PROCEDURES FOR THE ANALYSIS OF POLLUTANTS

Amendment of Regulations

On June 9, 1975, proposed amendments to the Guidelines Establishing Test Procedures for the Analysis of Pollutants (40 CFR 136) were published in the FEDERAL REGISTER (40 FR 24535) as required by section 304(g) of the Federal Water Pollution Control Act Amendments of 1972 (86 Stat. 816, et seq., Pub. L. 92—500, 1972) hereinafter referred to as the Act.

Section 304(g) of the Act requires that the Administrator shall promulgate guidelines establishing test procedures for the analysis of pollutants that shall include factors which must be provided in: (1) any certification pursuant to section 401 of the Act, or (2) any permit application pursuant to section 402 of the Act. Such test procedures are to be used by permit applicants to demonstrate that effluent discharges meet applicable pollutant discharge limitations and by the States and other enforcement activities in routine or random monitoring of effluents to verify compliance with pollution control measures.

Interested persons were requested to submit written comments, suggestions, or objections to the proposed amendments by September 7, 1975. One hundred and thirty-five letters were received from commenters. The following categories of organizations were represented by the commenters: Federal agencies accounted for twenty-four responses; State agencies accounted for twenty-six responses; local agencies accounted for seventeen responses; regulated major dischargers accounted for forty-seven responses; trade and professional organizations accounted for eight responses; analytical instrument manufacturers and vendors accounted for seven responses; and analytical service laboratories accounted for six responses.

All comments were carefully evaluated by a technical review committee. Based upon the review of comments, the following principal changes to the proposed amendments were made:

(A) *Definitions.* Section 136.2 has been amended to update references: Twenty commenters, representing the entire spectrum of responding groups pointed out that the references cited in §§136.2(f), 136.2(g), and 136.2(h) were out of date; §§136.2(f), 136.2(g), and 136.2(h), respectively, have been amended to show the following editions of the standard references: "14th Edition of Standard Methods for the Examination of Water and Waste Water;" "1974 EPA Manual of Methods for the Analysis of Water and Waste;" and "Part 31, 1975 Annual Book of ASTM Standards."

(B) *Identification of Test Procedures.* Both the content and format of § 136.3, "Table I, List of Approved Test Procedures" have been revised in response to twenty-one comments received from State and local governments, major regulated dischargers, professional and trade associations, and analytical laboratories.

Table I has been revised by:

(1) The addition of a fourth column of references which includes procedures of the United States Geological Survey which are equivalent to previously approved methods.

(2) The addition of a fifth column of miscellaneous references to procedures which are equivalent to previously approved methods.

(3) Listing generically related parameters alphabetically within four subcategories: bacteria, metals, radiological and residue, and by listing these subcategory headings in alphabetic sequence relative to the remaining parameters.

(4) Deleting the parameter "Algicides" and by entering the single relevant algicide, "Pentachlorophenol" by its chemical name.

(C) *Clarification of Test Parameters.* The conditions for analysis of several parameters have been more specifically defined as a result of comments received by the Agency:

(1) In response to five commenters representing State or local governments, major dischargers, or analytical instrument manufacturers, the end-point for the

alkalinity determination is specifically designated as pH 4.5.

(2) Manual digestion and distillation are still required as necessary preliminary steps for the Kjeldahl nitrogen procedure. Analysis after such distillation may be by Nessler color comparison, titration, electrode, or automated phenolate procedures.

(3) In response to eight commenters representative of Federal and State governments, major dischargers, and analytical instrument manufacturers, manual distillation at pH 9.5 is now specified for ammonia measurement.

(D) *New Parameters and Analytical Procedures.* Forty-four new parameters have been added to Table I. In addition to the designation of analytical procedures for these new parameters, the following modifications have been made in analytical procedures designated in response to comments.

(1) The ortho-tolidine procedure was not approved for the measurement of residual chlorine because of its poor accuracy and precision. Its approval had been requested by seven commenters representing major dischargers, State, or local governments, and analytical instrument manufacturers. Instead, the N,N-diethyl-p-phenylenediamine (DPD) method is approved as an interim procedure pending more intensive laboratory testing. It has many of the advantages of the ortho-tolidine procedure such as low cost, ease of operation, and also is of acceptable precision and accuracy.

(2) The Environmental Protection Agency concurred with the American Dye Manufacturers' request to approve its procedure for measurement of color, and copies of the procedure are now available at the Environmental Monitoring and Support Laboratory, Cincinnati (EMSL—CI).

(3) In response to three requests from Federal, State governments, and dischargers, "hardness," may be measured as the sum of calcium and magnesium analyzed by atomic absorption and expressed as their carbonates.

(4) The proposal to limit measurement of fecal coliform bacteria in the presence of chlorine to only the "Most Probable Number" (MPN) procedure has been withdrawn in response to requests from forty-five commenters including State pollution control agencies, permit holders, analysts, treatment plant operators, and a manufacturer of analytical supplies. The membrane filter (MF) procedure will continue to be an approved technique for the routine measurement of fecal coliform in the presence of chlorine. However, the MPN procedure must be used to resolve controversial situations. The technique selected by the analyst must be reported with the data.

(5) A total of fifteen objections, representing the entire spectrum of commenters, addressed the drying temperatures used for measurement of residues. The use of different temperatures in drying of total residue, dissolved residue and suspended residue was cited as not allowing direct intercomparability between these measurements. Because the intent of designating the three separate residue parameters is to measure separate waste characteristics (low drying temperatures to measure volatile substances, high drying temperatures to measure anhydrous inorganic substances), the difference in drying temperatures for these residue parameters must be preserved.

(E) *Deletion of Measurement Techniques.* Some measurement techniques that had been proposed have been deleted in response to objections raised during the public comment period.

(1) The proposed infrared spectrophotometric analysis for oil and grease has been withdrawn. Eleven commenters representing Federal or State agencies and major dischargers claimed that this parameter is defined by the measurement procedure. Any alteration in the procedure would change the definition of the parameter. The Environmental Protection Agency agreed.

(2) The proposed separate parameter for sulfide at concentrations below 1 mg/l, has been withdrawn. Methylene blue spectrophotometry is now included in Table I as an approved procedure for sulfide analysis. The titrimetric iodine procedure for sulfide analysis may only be used for analysis of sulfide at concentrations in excess of one milligram per liter.

(F) *Sample Preservation and Holding Times.* Criteria for sample preservation and sample holding times were requested by several commenters. The reference for sample preservation and holding time criteria applicable to the Table I parameters is given in footnote (1) of Table I.

(G) *Alternate Test Procedures.* Comments pertaining to § 136.4, Application for Alternate Test Procedures, included objections to various obstacles within these procedures for expeditious approval of alternate test procedures. Four analytical instrument manufacturers commented that by limiting of application for review and/or approval of alternate test procedures to NPDES permit holders, § 136.4 became an impediment to the commercial development of new or improved measurement devices based on new measurement principles. Applications for such review and/or approval will now be accepted from any person. The intent of the alternate test procedure is to allow the use of measurement systems which are known to be equivalent to the approved test procedures in waste water discharges.

Applications for approval of alternate test procedures applicable to specific discharges will continue to be made only by NPDES permit holders, and approval of such applications will be made on a case-by-case basis by the Regional Administrator in whose Region the discharge is made.

Applications for approval of alternate test procedures which are intended for nationwide use can now be submitted by any person directly to the Director of the Environmental Monitoring and Support Laboratory in Cincinnati. Such applications should include a complete methods write-up, any literature references, comparability data between the proposed alternate test procedure and those already approved by the Administrator. The application should include precision and accuracy data of the proposed alternate test procedure and data confirming the general applicability of the test procedure to the industrial categories of waste water for which it is intended. The Director of the Environmental Monitoring and Support Laboratory, after review of submitted information, will recommend approval or rejection of the application to the Administrator, or he will return the application to the applicant for more information. Approval or rejection of applications for test procedures intended for nationwide use will be made by the Administrator, after considering the recommendation made by the Director of the Environmental Monitoring and Support Laboratory, Cincinnati. Since the Agency considers these procedures for approval of alternate test procedures for nationwide use to be interim procedures, we will welcome suggestions for criteria for approval of alternate test procedures for nationwide use. Interested persons should submit their written comments in triplicate on or before June 1, 1977 to: Dr. Robert B. Medz, Environmental Protection Technologist, Monitoring Quality Assurance Standardization, Office of Monitoring and Technical Support (RD—680), Environmental Protection Agency, Washington, D.C. 20460.

(H) *Freedom of Information.* A copy of all public comments, an analysis by parameter of those comments, and documents providing further information on the rationale for the changes made in the final regulation are available for inspection and copying at the Environmental Protection Agency Public Information Reference Unit, Room 2922, Waterside Mall, 401 M Street, SW., Washington, D.C. 20460, during normal business hours. The EPA information regulation 40 CFR 2 provides that a reasonable fee may be charged for copying such documents.

Effective date: These amendments become effective on April 1, 1977.

Dated: November 19, 1976.

JOHN QUARLES,
Acting Administrator,
Environmental Protection Agency.

Chapter I, Subchapter D, of Title 40, Code of Federal Regulations is amended as follows:

1. In § 136.2, paragraphs (f), (g), and (h) are amended to read as follows:

§ 136.2 Definitions.

* * * * *

(f) "Standards Methods" means *Standard Methods for the Examination of Water and Waste Water*, 14th Edition, 1976. This publication is available from the American Public Health Association, 1015 18th Street, N.W., Washington, D.C. 20036.

(g) "ASTM" means *Annual Book of Standards, Part 31, Water, 1975*. This publication is available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

(h) "EPA Methods" means *Methods for Chemical Analysis of Water and Waste, 1974*. Methods Development and Quality Assurance Research Laboratory, National Environmental Research Center, Cincinnati, Ohio 45268; U.S. Environmental Protection Agency, Office of Technology Transfer, Industrial Environmental Research Laboratory, Cincinnati, Ohio 45268. This publication is available from the Office of Technology Transfer.

2. In § 136.3, the second sentence of paragraph (b) is amended, and a new paragraph (c) is added to read as follows:

§ 136.3 Identification of test procedures.

* * * * *

(b) * * * Under such circumstances, additional test procedures for analysis of pollutants may be specified by the Regional Administrator or the Director upon the recommendation of the Director of the Environmental Monitoring and Support Laboratory, Cincinnati.

(c) Under certain circumstances, the Administrator may approve, upon recommendation by the Director, Environmental Monitoring and Support Laboratory, Cincinnati, additional alternate test procedures for nationwide use.

3. ,Table I of § 136.3 is revised by listing the parameters alphabetically; by adding 44 new parameters; by adding a fourth column under references listing equivalent United States Geological Survey methods; by adding a fifth column under references listing miscellaneous equivalent methods; by deleting footnotes 1 through 7 and adding 24 new footnotes to read as follows:

* * * * *

TABLE I.—*List of approved test procedures*[1]

Parameter and units	Method	1974 EPA methods	14th ed. standard methods	References (page nos.)		Other approved methods
				Pt. 31 1975 ASTM	USGS methods[2]	
1. Acidity, as $CaCO^3$, milligrams per liter.	Electrometric end point (pH of 8.2) or phenolphthalein end point.	1	273(4d)	116	40	[3](607)
2. Alkalinity, as $CaCO^3$, milligrams per liter.	Electrometric titration (only to pH 4.5) manual or automated, or equivalent automated methods.	3	278	111	41	[3](607)
		5				
3. Ammonia (as N), milligrams per liter.	Manual distillation[4] (at pH 9.5) followed by nesslerization, titration, electrode, Automated phenolate.		410			
		159	412	237	116	[3](614)
		165				
		168	616			
BACTERIA						
4. Coliform (fecal)[5], number per 100 ml.	MPN;[6] membrane filter		922			
			937		[7](45)	
5. Coliform (fecal)[5] in presence of chlorine, number per 100 ml.	do.[6] [8]		922			
			928,937			
6. Coliform (total),[5] number per 100 ml.	do.[6]		916			
			928		[7](35)	
7. Coliform (total)[5] in presence of chlorine, number per 100 ml.	MPN;[6] membrane filter with enrichment		916			
			933			
8. Fecal streptococci,[5] number per 100 ml.	MPN;[6] membrane filter; plate count.		943			
			944		[7](50)	
			947			

Parameter and units	Method	1974 EPA methods	14th ed. standard methods	References (page nos.)		Other approved methods
				Pt. 31 1975 ASTM	USGS methods[2]	
9. Benzidine, milligrams per liter	Oxidation—colorimetric[6]					
10. Biochemical oxygen demand, 5-d (BOD$_5$), milligrams per liter.	Winkler (Azide modification) or electrode method		543		[7](50)	[10](17)
11. Bromide, milligrams per liter . .	Titrimetric, iodine-iodate . . .	14		323	58	
12. Chemical oxygen demand (COD), milligrams per liter	Dichromate reflux	20	550	472	124	[9](610) [10](17)
13. Chloride, milligrams per liter . .	Silver nitrate; mercuric nitrate; or automated colorimetric-ferricyanide.	29 31	303 304 613.	267 265	[11](46).	[3](610)
14. Chlorinated organic compounds (except pesticides), milligrams per liter.	Gas chromatography[12]					
15. Chlorine—total residual, milligrams per liter.	Iodometric titration, amperometric or starch-iodine end-point; DPD colorimetric or Titrimetric methods (these last 2 are interim methods pending laboratory testing).	35	318 322 332 329	278		
16. Color, platinum cobalt units or dominant wave length, hue, luminance, purity.	Colorimetric; spectrophotometric; or ADMI procedure.[13]	36 39	64 66		82	
17. Cyanide, total,[14] milligrams per liter	Distillation followed by silver nitrate titration or pyridine pyrazolone (or barbituric acid) colorimetric.	40	361	503	85	[10](22)
18. Cyanide amenable to chlorination, milligrams per liter.	. . . . . do.	49	376	505		
19. Dissolved oxygen, milligrams per liter.	Winkler (Azide modification) or electrode method.	51 56	443 450	368	126	[3](609)
20. Fluoride, milligrams per liter . .	Distillation[4] followed by ion electrode; SPADNS; or automated complexone.	65 59 61	389 391 393 614	307 305	93	
21. Hardness—Total, as CaCO$_3$, milligrams per liter.	EDTA titration; automated colorimetric; or atomic absorption (sum of Ca and Mg as their respective carbonates).	68 70	202	161	94	[3](617)
22. Hydrogen ion (pH), pH units.	Electrometric measurement.	239	460	178	129	[3](606)
23. Kjeldahl nitrogen (as N), milligrams per liter.	Digestion and distillation followed by nesslerization, titration, or electrode; automated digestion automated phenolate.	175 165 182	437		122	[3](612)
METALS						
24. Aluminum—Total, milligrams per liter.	Digestion[15] followed by atomic absorption[16] or by colorimetric (Eriochrome Cyanine R).	92	152 171		[11](19)	
25. Aluminum—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced methods for total aluminum.					
26. Antimony—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[16]	94				
27. Antimony—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total antimony.					
28. Arsenic—Total, milligrams per liter.	Digestion followed by silver diethyldithiocarbamate; or atomic absorption.[16] [18]	9 95	285 283 159		[11](31) [11](37)	
29. Arsenic—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total arsenic.					
30. Barium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[16]	97	152		52	
31. Barium—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total barium.					

Parameter and units	Method	1974 EPA methods	14th ed. standard methods	References (page nos.)		Other approved methods
				Pt. 31 1975 ASTM	USGS methods[2]	
32. Beryllium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption[16] or by colorimetric (Aluminon)	99	152 177		53	
33. Beryllium—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total beryllium.					
34. Boron—Total, milligrams per liter.	Colorimetric (Curcumin)	13	287			
35. Boron—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total boron.					
36. Cadmium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption[16] or by colorimetric (Dithizone).	101	148 182	345	62	[3](619)[10](37)
37. Cadmium—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total cadmium.					
38. Calcium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption; or EDTA titration.	103	148 189	345	66	
39. Calcium—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total calcium.					
40. Chromium VI, milligrams per liter.	Extraction and atomic absorption; colorimetric (Diphenylcarbazide).	89,105	192		76 75	
41. Chromium VI—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for chromium VI.					
42. Chromium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption[16] or by colorimetric (Diphenylcarbazide).	105	148 192	345 286	78 77	[3](619)
43. Chromium—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total chromium.					
44. Cobalt—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[16]	107	148	345	80	[10](37)
45. Cobalt—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total cobalt.					
46. Copper—Total, milligrams per liter.	Digestion[15] followed by atomic absorption[16] or by colorimetric (Neocuproine).	108	148 196	345 293	83	[3](619) [10](37)
47. Copper—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total copper.					
48. Gold—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[19]					
49. Iridium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption [19]					
50. Iron—Total, milligrams per liter.	Digestion[15] followed by atomic absorption[16] or by colorimetric (Phenanthroline).	110	148 208	345 326	102	[3](619)
51. Iron—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total iron.					
52. Lead—Total, milligrams per liter.	Digestion[15] followed by atomic absorption[16] or by colorimetric (Dithizone).	112	148 215	345	105	[3](619)
53. Lead—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total lead.					
54. Magnesium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption, or gravimetric.	114	148 221	345	109	[3](619)
55. Magnesium—Dissolved milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total magnesium.					
56. Manganese--Total milligrams per liter.	Digestion[15] followed by atomic absorption[16] or by colorimetric (Persulfate or periodate).	116	148 225,227	345	111	[3](619)

Parameter and units	Method	1974 EPA methods	14th ed. standard methods	References (page nos.)		Other approved methods
				Pt. 31 1975 ASTM	USGS methods[2]	
57. Manganese—Dissolved milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total manganese.					
58. Mercury—Total, milligrams per liter.	Flameless atomic absorption.	118	156	338	[11](51)	
59. Mercury—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total mercury.					
60. Molybdenum—Total, milligrams per liter.	Digestion[15] followed by atomic absorption[16]	139		350		
61. Molybdenum—Dissolved, milligrams per liter.	0.45 micron filtration[1] followed by referenced method for total molybdenum.					
62. Nickel—Total, milligrams per liter.	Digestion[15] followed by atomic absorption [16] or by colorimetric (Heptoxime).	141	148	345	115	
63. Nickel—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total nickel.					
64. Osmium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[19]					
65. Palladium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[19]					
66. Platinum—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[19]					
67. Potassium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption, colorimetric (Cobaltinitrite), or by flame photometric.	143	235 234	403	134	[3](620)
68. Potassium—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total potassium.					
69. Rhodium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[19]					
70. Ruthenium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[19]					
71. Selenium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[18, 19]	145	159			
72. Selenium—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total selenium.					
73. Silica--Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by colorimetric (Molybdosilicate).	274	487	398	139	
74. Silver—Total,[20] milligrams per liter.	Digestion[15] followed by atomic absorption[16] or by colorimetric (Dithizone).	146	148 243		142	[3](619) [10](37)
75. Silver—Dissolved,[20] milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total silver.					
76. Sodium--Total, milligrams per liter.	Digestion[15] followed by atomic absorption or by flame photometric.	147	250	403	143	[3](621)
77. Sodium—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total sodium.					
78. Thallium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[16]	149				
79. Thallium—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total thallium.					
80. Tin—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[16]	150			[11](65)	
81. Tin—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total tin.					
82. Titanium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption.[16]	151				
83. Titanium—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total titanium.					

Parameter and units	Method	1974 EPA methods	14th ed. standard methods	References (page nos.)		Other approved methods
				Pt. 31 1975 ASTM	USGS methods[3]	
84. Vanadium—Total, milligrams per liter.	Digestion[15] followed by atomic absorption[16] or by colorimetric (Gallic acid).	153	152 260	 441	 [11](67)	
85. Vanadium—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total vanadium.					
86. Zinc—Total, milligrams per liter.	Digestion[15] followed by atomic absorption[16] or by colorimetric (Dithizone).	155	148 265	345	159	[3](619) [10](37)
87. Zinc—Dissolved, milligrams per liter.	0.45 micron filtration[17] followed by referenced method for total zinc.					
88. Nitrate (as N), milligrams per liter.	Cadmium reduction; brucine sulfate; automated cadmium or hydrazine reduction.[21]	201 197 207	423 427 620	 358	 119	 [3](614) [10](28)
89. Nitrate (as N), milligrams per liter.	Manual or automated colorimetric (Diazotization).	215	434		121	
90. Oil and grease, milligrams per liter.	Liquid-liquid extraction with trichloro-trifluoro-ethane-gravimetric.	229	515			
91. Organic carbon; total (TOC), milligrams per liter.	Combustion—Infrared method.[22]	236	532	467	[23](4)	
92. Organic nitrogen (as N), milligrams per liter.	Kjeldahl nitrogen minus ammonia nitrogen.	175,159	437		122	[3](612,614)
93. Orthophosphate (as P), milligrams per liter.	Manual or automated ascorbic acid reduction.	249 256	481 624	384	131	[3](621)
94. Pentachlorophenol, milligrams per liter.	Gas chromatography[12]					
95. Pesticides, milligrams per liter.	do.[12]		555	529	[23](24)	
96. Phenols, milligrams per liter.	Colorimetric, (4 AAP)	241	582	545		
97. Phosphorus (elemental), milligrams per liter.	Gas chromatography[24]					
98. Phosphorus; total (as P), milligrams per liter.	Persulfate digestion followed by manual or automated ascorbic acid reduction.	249 256	476,481 624	384	133	[3](621)
RADIOLOGICAL						
99. Alpha—Total, pCi per liter.	Proportional or scintillation counter.		648	591 [11]	[25](75+78)	
100. Alpha—Counting error, pCi per liter.	do.		648	594	[11](79)	
101. Beta—Total, pCi per liter	Proportional counter		648	601 [11]	[25](75+78)	
102. Beta—Counting error, pCi per liter.	do.		648	606	[11](79)	
103. (a) Radium—Total, pCi per liter.	do.		661	661		
(b) ^{226}Ra, pCi per liter	Scintillation counter		667		[11](81)	
RESIDUE						
104. Total, milligrams per liter	Gravimetric, 103 to 105°C	270	91			
105. Total dissolved (filterable), milligrams per liter.	Glass fiber filtration, 180°C	266	92			
106. Total suspended (nonfilterable), milligrams per liter.	Glass fiber filtration, 103 to 105°C	268	94			
107. Settleable, milliliters per liter or milligrams per liter.	Volumetric or gravimetric		95			
108. Total volatile, milligrams per liter.	Gravimetric, 550°C	272	95			
109. Specific conductance, micromhos per centimeter at 25°C.	Wheatstone bridge conductimetry	275	71	120	148	[3](606)
110. Sulfate (as SO_4), milligrams per liter.	Gravimetric; turbidimetric; or automated colorimetric (barium chloranilate).	 277 279	493 496	424 425		[3](624) [3](623)

Parameter and units	Method	1974 EPA methods	14th ed. standard methods	References (page nos.)		Other approved methods
				Pt. 31 1975 ASTM	USGS methods[2]	
111. Sulfide (as S), milligrams per liter.	Titrimetric—Iodine for levels greater than 1 mg per liter;	284	505		154	
	Methylene blue photometric.		503			
112. Sulfite (as SO_3), milligrams per liter.	Titrimetric, iodine-iodate	285	508	435		
113. Surfactants, milligrams per liter.	Colorimetric (Methylene blue).	157	600	494	[20](11)	
114. Temperature, degrees C	Calibrated glass or electrometric thermometer.	286	125		[26](31)	
115. Turbidity, NTU	Nephelometric	295	132	223	156	

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[1] Recommendations for sampling and preservation of samples according to parameter measured may be found in "Methods for Chemical Analysis of Water and Wastes, 1974" U.S. Environmental Protection Agency, table 2, pp. viii-xii.

[2] All page references for USGS methods, unless otherwise noted, are to Brown, E., Skougstad, M. W., and Fishman, M. J., "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," U.S. Geological Survey Techniques of Water-Resources Inv., book 5, ch. A1, (1970).

[3] EPA comparable method may be found on indicated page of "Official Methods of Analysis of the Association of Official Analytical Chemists" methods manual, 12th ed. (1975).

[4] Manual distillation is not required if comparability data on representative effluent samples are on company file to show that this preliminary distillation step is not necessary; however, manual distillation will be required to resolve any controversies.

[5] The method used must be specified.

[6] The 5 tube MPN is used.

[7] Slack, K. V. and others, "Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples: U.S. Geological Survey Techniques of Water-Resources Inv. book 5, ch. A4 (1973)."

[8] Since the membrane filter technique usually yields low and variable recovery from chlorinated wastewaters, the MPN method will be required to resolve any controversies.

[9] Adequately tested methods for benzidine are not available. Until approved methods are available, the following interim method can be used for the estimation of benzidine: (1) "Method for Benzidine and Its Salts in Wastewaters," available from Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

[10] American National Standard on Photographic Processing Effluents, Apr. 2, 1975. Available from ANSI, 1430 Broadway, New York, N.Y. 10018.

[11] Fishman, M. J. and Brown, Eugene, "Selected Methods of the U.S. Geological Survey for Analysis of Wastewaters," (1976) open-file report 76-177.

[12] Procedures for pentachlorophenol, chlorinated organic compounds, and pesticides can be obtained from the Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

[13] Color method (ADMI procedure) available from Environmental Monitoring and Support Laboratory, U.S., Environmental Protection Agency, Cincinnati, Ohio 45268.

[14] For samples suspected of having thiocyanate interference, magnesium chloride is used as the digestion catalyst. In the approved test procedure for cyanides, the recommended catalysts are replaced with 20 ml of a solution of 510 g/l magnesium chloride ($MgCl_2$-$6H_2O$). This substitution will eliminate thiocyanate interference for both total cyanide and cyanide amendable to chlorination measurements.

[15] For the determination of total metals the sample is not filtered before processing. Because vigorous digestion procedures may result in a loss of certain metals through precipitation, a less vigorous treatment is recommended as given on p. 83 (4.1.4) of "Methods for Chemical Analysis of Water and Wastes" (1974). In those instances where a more vigorous digestion is desired the procedure on p. 82 (4.1.3) should be followed. For the measurement of the noble metal series (gold, iridium, osmium, palladium, platinum, rhodium and ruthenium), an aqua regia digestion is to be substituted as follows: Transfer a representative aliquot of the well-mixed sample to a Griffin beaker and add 3 ml of concentrated redistilled HNO_3. Place the beaker on a steam bath and evaporate to dryness. Cool the beaker and cautiously add a 5 ml portion of aqua regia. (Aqua regia is prepared immediately before use by carefully adding 3 volumes of concentrated HCl to one volume of concentrated HNO_3.) Cover the beaker with a watch glass and return to the steam bath. Continue heating the covered beaker for 50 min. Remove cover and evaporate to dryness. Cool and take up the residue in a small quantity of 1:1 HCl. Wash down the beaker walls and wash glass with distilled water and filter the sample to remove silicates and other insoluble material that could clog the atomizer. Adjust the volume to some predetermined value based on the expected metal concentration. The sample is now ready for analysis, .

[16] As the various furnace devices (flameless AA) are essentially atomic absorption techniques, they are considered to be approved test methods. Methods of standard addition are to be followed as noted in p. 78 of "Methods for Chemical Analysis of Water and Wastes," 1974.

[17] Dissolved metals are defined as those constitutents which will pass through a 0.45 μm membrane filter. A prefiltration is permissible to free the sample from larger suspended solids. Filter the sample as soon as practical after collection using the first 50 to 100 ml to rinse the filter flask. (Glass or plastic filtering apparatus are recommended to avoid possible contamination.) Discard the portion used to rinse the flask and collect the required volume of filtrate. Acidify the filtrate with 1:1 redistilled HNO_3 to a pH of 2. Normally, 3 ml of (1:1) acid per liter should be sufficient to preserve the samples.

[18] See "Atomic Absorption Newsletter" vol. 13,75 (1974). Available from Perkin-Elmer Corp., Main Ave., Norwalk, Conn. 06852.

[19] Method available from Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

[20] Recommended methods for the analysis of silver in industrial wastewaters at concentrations of 1 mg/l and above are inadequate where silver exists as an inorganic halide. Silver halides such as the bromide and chloride are relatively insoluble in reagents such as nitric acid but are readily soluble in an aqueous buffer of sodium thiosulfate and sodium hydroxide to a pH of 12. Therefore, for levels of silver above 1 mg/l 20 ml of sample should be diluted to 100 ml by adding 40 ml each of 2M $Na_2S_2O_3$ and 2M of NaOH. Standards should be prepared in the same manner. For levels of silver below 1 mg/l the recommended method is satisfactory.

[21] An automated hydrazine reduction method is available from the Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

[22] A number of such systems manufactured by various companies are considered to be comparable in their performance. In addition, another technique, based on combustion-methane detection is also acceptable.

[23] Goerlitz, D., Brown, E., "Methods for Analysis of Organic Substances in Water": U.S. Geological Survey Techniques of Water-Resources Inv., book 5, ch. A3 (1972).

[24] R. F. Addison and R. G. Ackman, "Direct Determination of Elemental Phosphorus by Gas-Liquid Chromatography," "Journal of Chromatography," vol. 47, No. 3, pp. 421—426, 1970.

[25] The method found on p. 75 measures only the dissolved portion while the method on p. 78 measures only suspended. Therefore, the 2 results must be added together to obtain "total."

[26] Stevens, H. H., Ficke, J. F., and Smoot, G. F., "Water Temperature—Influential Factors, Field Measurement and Data Presentation: U.S. Geological Survey Techniques of Water Resources Inv., book 1 (1975)."

4. In § 136.4, the second sentence of paragraph (c) is amended by deleting the word "subchapter" immediately following the phrase "procedure under this" and immediately preceding the word "shall" and replaced with the phrase "paragraph c;" and § 136.4 is amended by adding a new paragraph (d) to read as follows:

§ 136.4 Application for alternate test procedures.

* * * * *

(c) * * * Any application for an alternate test procedure under this paragraph (c) shall: * * *

(d) An application for approval of an alternate test procedure for nationwide use may be made by letter in triplicate to the Director, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268. Any application for an alternate test procedure under this paragraph (d) shall:

(1) Provide the name and address of the responsible person or firm making the application.

(2) Identify the pollutant(s) or parameter(s) for which nationwide approval of an alternate testing procedure is being requested.

(3) Provide a detailed description of the proposed alternate procedure, together with references to published or other studies confirming the general applicability of the alternate test procedure to the pollutant(s) or parameter(s) in waste water discharges from representative and specified industrial or other categories.

(4) Provide comparability data for the performance of the proposed alternate test procedure compared to the performance of the approved test procedures.

§ 136.5 [Amended]

5. In § 136.5, paragraph (a) is amended by inserting the phrase "proposed by the responsible person or firm making the discharge" immediately after the words "test procedure" and before the period that ends the paragraph.

6. In § 136.5, paragraph (b) is amended by inserting in the first sentence the phrase "proposed by the responsible person or firm making the discharge" immediately after the words "such application" and immediately before the comma. The second sentence of paragraph (b) is amended by deleting the phrase "Methods Development and Quality Assurance Research Laboratory" immediately after the phrase "State Permit Program and to the Director of the" at the end of the sentence, and inserting in its place the phrase "Environmental Monitoring and Support Laboratory, Cincinnati."

7. In § 136.5, paragraph (c) is amended by inserting the phrase "proposed by the responsible person or firm making the discharge" immediately after the phrase "application for an alternate test procedure" and immediately before the comma; and by deleting the phrase "Methods Development and Quality

Assurance Laboratory" immediately after the phrase "application to the Director of the" and immediately before the phrase "for review and recommendation" and inserting in its place the phrase "Environmental Monitoring and Support Laboratory, Cincinnati."

8. In § 136.5, the first sentence of paragraph (d) is amended by inserting the phrase, "proposed by the responsible person or firm making the discharge," immediately after the phrase, "application for an alternate test procedure," and immediately before the comma.

The second sentence of paragraph (d) is amended by deleting the phrase, "Methods Development and Quality Assurance Research Laboratory," immediately after the phrase, "to the Regional Administrator by the Director of the," and immediately preceding the period ending the sentence and inserting in its place the phrase, "Environmental Monitoring and Support Laboratory, Cincinnati."

The third sentence of paragraph (d) is amended by deleting the phrase, "Methods Development and Quality Assurance Research Laboratory," immediately after the phrase, "forwarded to the Director," and immediately before the second comma and by inserting in its place the phrase, "Environmental Monitoring and Support Laboratory, Cincinnati."

9. Section 136.5 is amended by the addition of a new paragraph (e) to read as follows:

§ 136.5 Approval of alternate test procedures.

* * * * *

(e) Within ninety days of the receipt by the Director of the Environmental Monitoring and Support Laboratory, Cincinnati of an application for an alternate test procedure for nationwide use, the Director of the Environmental Monitoring and Support Laboratory, Cincinnati shall notify the applicant of his recommendation to the Administrator to approve or reject the application, or shall specify additional information which is required to determine whether to approve the proposed test procedure. After such notification, an alternate method determined by the Administrator to satisfy the applicable requirements of this part shall be approved for nationwide use to satisfy the requirements of this subchapter; alternate test procedures determined by the Administrator not to meet the applicable requirements of this part shall be rejected. Notice of these determinations shall be submitted for publication in the FEDERAL REGISTER not later than 15 days after such notification and determination is made.

[FR Doc. 76—35032 Filed 11—30—76; 8:45 am]

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

PART 136—GUIDELINES ESTABLISHING TEST PROCEDURES FOR THE ANALYSIS OF POLLUTANTS

Amendment of Regulations; Corrections

In FR Doc. 76—35032 appearing at pages 52780 to 52786 in the FEDERAL REGISTER of Wednesday, December 1, 1976, the following changes should be made:

§ 136.3 [Amended]

1. On Page 52783, for parameter number 62, Nickel—Total, add "232" to the page references in the column under the 14th edition of Standard Methods opposite the colorimetric method designation.

2. On page 52784, for parameter number 89, change the parameter designation from "Nitrate" to "Nitrite."

3. On page 52784, for parameter number 96, Phenols, delete the present method designation, "Colorimetric, (4AAP)," and replace it with the method designation, "Distillation followed by colorimetric, (4AAP)"; delete the page reference in the column under the 14th edition of Standard Methods, "582," and replace it with page number "574."

Dated: January 10, 1977.

WILSON K. TALLEY,
Assistant Administrator for Research and Development

[FR Doc. 77-1453 Filed 1—17—77; 8:45 am]

METRIC CONVERSION TABLES

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents*
Length	meter	m	*Basic SI unit*	39.37 m = 3.281 ft = 1.094 yd
	kilometer	km		0.6214 mi
	millimeter	mm		0.03937 in
	micrometer or micron	µm or µ		3.937×10^{-5} in = 1×10^{4} Å
Area	square meter	m^2		10.76 sq ft = 1.196 sq yd
	square kilometer	km^2		0.3861 sq mi = 247.1 acres
	square millimeter	mm^2		0.001550 sq in
	hectare	ha	The hectare (10,000 m^2) is a recognized multiple unit and will remain in international use.	2.471 acres
Volume	cubic meter	m^3		35.31 cu ft = 1.308 cu yd
	litre	l		1.057 qt = 0.2642 gal = 0.8107×10^{-4} acre ft
Mass	kilogram	kg	*Basic SI unit*	2.205 lb
	gram	g		0.03527 oz = 15.43 gr
	milligram	mg		0.01543 gr
	tonne	t	1 tonne = 1,000 kg	0.9842 ton (long) = 1.102 ton (short)
Force	newton	N	The newton is that force that produces an acceleration of 1 m/s^2 in a mass of 1 kg.	0.2248 lb = 7.233 poundals
Moment or torque	newton meter	N-m	The meter is measured perpendicular to the line of action of the force N. Not a joule.	0.7375 lb-ft 23.73 poundal-ft
Flow (volumetric)	cubic meter per second	m^3/s		15.850 gpm = 2,119 cfm
	liter per second	l/s		15.85 gpm

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents*
Velocity linear	meter per second	m/s		3.281 fps
	millimeter per second	mm/s		0.003281 fps
	kilometers per second	km/s		2,237 mph
angular	radians per second	rad/s		9.549 rpm
Viscosity	pascal second	Pa-s		0.6722 poundal(s)/sq ft
	centipoise	Z		1.450×10^{-7} Reyn (µ)
Pressure or stress	newton per square meter or pascal	N/m^2 or Pa		0.0001450 lb/sq in
	kilonewton per square meter or kilopascal	kN/m^2 or kPa		0.14507 lb/sq in
	bar	bar		14.50 lb/sq in
Temperature	Celsius (centigrade)	°C		(°F−32)/1.8
	Kelvin (abs.)	°K		°C + 273.2
Work, energy, quantity of heat	joule	J	1 joule = 1 N-m where meters are measured along the line of action of force N.	2.778×10^{-7} kw-hr = 3.725×10^{-7} hp-hr = 0.7376 ft-lb = 9.478×10^{-4} Btu
	kilojoule	kJ		2.778×10^{-4} kw-hr
Power	watt	W	1 watt = 1 J/s	44.25 ft-lbs/min
	kilowatt	kW		1.341 hp
	joule per second	J/s		3.412 Btu/hr

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents*
Precipitation, run-off, evaporation	millimeter	mm	For meteorological purposes, it may be convenient to measure precipitation in terms of mass/unit area (kg/m^2). 1 mm of rain = 1 kg/m^2	
Flow	cubic meter per second	m^3/s		35.31 cfs
	liter per second	l/s		15.85 gpm
Discharges or abstractions, yields	cubic meter per day	m^3/d	1 l/s = 86.4 m^3/d	0.1835 gpm
	cubic meter per year	$m^3/year$		264.2 gal/year
Usage of water	liter per person per day	l/person/day		0.2642 gcpd

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents*
Density	kilogram per cubic meter	kg/m^3	The density of water under standard conditions is 1,000 kg/m^3 or 1,000 g/l or 1 g/ml.	0.06242 lb/cu ft
Concentration	milligram per liter (water)	mg/l		1 ppm
BOD loading	kilogram per cubic meter per day	$kg/m^3/d$		0.06242 lb/cu ft/day
Hydraulic load per unit area, e.g., filtration rates	cubic meter per square meter per day	$m^3/m^2/d$	If this is converted to a velocity, it should be expressed in mm/s (1mm/s = 86.4 $m^3/m^2/day$).	3.281 cu ft/sq ft/day
Air supply	cubic meter or liter of free air per second	m^3/s l/s		
Optical units	lumen per square meter	$lumen/m^2$		0.09294 ft candle/sq ft

*Miles are U.S. statute, qt and gal are U.S. liquid, and oz and lb are avoirdupois.

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